THE

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OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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ERRATA ET CORRIGENDA.

Page 197, line 12 from bottom. *for* these *read* there.

Pages 305 and 307, line 10 from bottom *for* Peny *read* Perry.

Page 306, line 15 *for* Bodun *read* Brown.

Page 307, line 30 for *magnacensis* read *gaspiensis*, and delete footnote.

Page 326, line 13 from bottom, *for* DENTIPOR *read* DENTIPORA.

Page 406, explanation of Fig. 1, for *Fissile* read *Felsite.*

Page 597, line 3 from bottom, *for* MANSELLLI *read* MANSELII.

Page 597, line 2 from bottom, for *Mansellii* read *Manselii.*

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Vol. XXXVII.

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1. Note *on the* Occurrence *of* Remains *of* Recent Plants *in* Brown Iron-ore. By J. Arthur Phillips, Esq., F.G.S. (Read November 3, 1880.)

This bed of fossiliferous iron-ore is situated at Rio Tinto, in the province of Huelva, Spain, and is in close proximity to the celebrated copper-mines of that name.

In this portion of Southern Spain deposits of cupreous iron pyrites, consisting of a series of lenticular masses of ore, having a general direction a little north of east and south of west, extend from Aznalcollar, near Seville, in the east, for a distance of more than seventy miles westward to within the Portuguese frontier.

At Rio Tinto the deposits of this mineral are very extensive, and consist of a compact and intimate admixture of iron pyrites with a little copper pyrites, through which strings of the latter mineral sometimes ramify.

Although these mines appear to have been worked, and the copper smelted upon the spot, from time immemorial, it is evident from the vast heaps of furnace-slags, and from the extent of the various other remains in which coins and inscriptions of the reigns of the Emperors from Nerva to Honorius have been discovered, that their great development under the Romans took place during the first four centuries of the Christian era. After the fall of the Roman empire they seem to have been abandoned down to as late as the year 1727, from which date they were intermittently worked by the Spanish

Government and by various private speculators until 1873, when they were purchased by an English company. The extent of the mining and metallurgical operations anciently carried on in this district will be understood when it is stated that at Rio Tinto alone, in addition to hundreds of Roman shafts and miles of Roman galleries, the heaps of copper slags resulting from the smelting at that period cannot amount to much less than one and a half million of tons, and that there are large accumulations of similar ancient refuse at Tharsis, Buitron, and other mines.

As illustrating the care and skill of the metallurgists of that period it may be stated that each ton of their slags seldom contains above three pounds of copper.

The prevailing rock throughout this region is clay-slate, which, from the evidence of various fossils found by Mr. A. Hill, Mr. G. W. Clement, and other officers on the staff at Rio Tinto, is apparently of Silurian age. These specimens were kindly examined by Mr. R. Etheridge, who did not hesitate to identify them as belonging to that period.

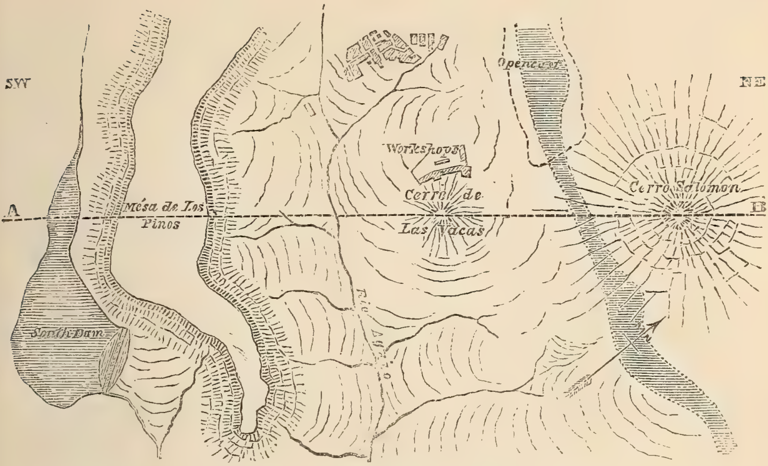
These slates are, in places, broken through by large dykes of quartz-porphyry, which frequently form one of the walls of the various deposits of cupreous pyrites.

The fossiliferous iron-ore which is the immediate subject of this note forms a cap one kilometre long, with an average width of one hundred and thirty metres, on the top of the Mésa de los Pinos, nine hundred metres south of the open cutting at Rio Tinto. Its surface is approximately level, but it varies in depth from one to seventeen metres in accordance with the conformation of the surface of the slate upon which it lies; the rock beneath it is bleached and to some extent decomposed.

The order and relative positions of the several formations will be best understood on referring to the accompanying plan and section (figs. 1, 2), for which I am indebted to Mr. Neil Kennedy, a gentleman in charge of a portion of the work at the mines, through whose kindness I am also enabled to lay specimens of the fossiliferous iron-ore upon the table.

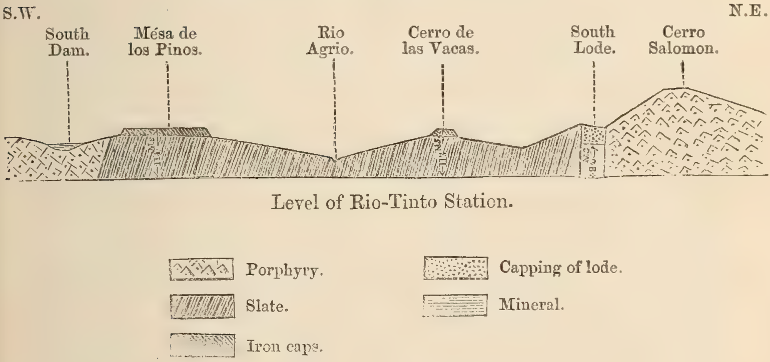
On the extreme right of the section is a broad porphyritic dyke forming the north wall of the south lode, next to which is the lode itself, which at this point has only one third of its greatest width. Next in succession, to the south, comes a band of slate, which is again penetrated on the left by a broad dyke of quartz-porphyry. It will be observed that the upper part of the vein has, to a considerable depth, been converted into a ferruginous capping (gossan), of which a large portion has been removed by denudation. The stratum of iron-ore forming the surface at the Mésa de los Pinos is shown with precipitous sides; and a small patch of a similar formation occurs, at within a metre of the same elevation, at the Cerro de las Vacas. Numerous fissures occur in the surface of the larger deposit of iron-ore, and out of these pine-trees formerly grew in considerable numbers, their presence giving the name to the locality; these were eventually destroyed by sulphurous fumes

Fig. 1.—*Plan of part of Rio Tinto.*



Scale of Plan and Section $\frac{1}{15,000}$.

Fig. 2.—*Section in line* A B *on Plan.*



resulting from the metallurgical operations which were carried on upon the declivity of the opposite hill.

In some instances the decomposed clay-slate has been partially removed from beneath the iron-ore, from which blocks have been detached, and have slidden a considerable distance down the surface of the slaty declivity.

A specimen of this iron-ore, analyzed in my laboratory, afforded the following results:—

Water	hygrometric	1·40
	combined	11·85
Silica		1·53
Ferric oxide		84·65
Alumina		trace.
Phosphoric anhydride		·14
Sulphur		·23
		99·80

It follows that this is a rich ore of iron of fairly good quality; and as there is now a well-appointed railway in its immediate proximity, it is probable that under moderately favourable conditions of the iron trade it may be worked with advantage.

During the process of quarrying this ironstone for exportation, Mr. Kennedy first observed the presence of fossil remains of what appeared to be leaves and seeds of many of the plants still growing in the neighbourhood, as well as of several well-preserved beetles.

All doubt as regards the recent character of these fossils is, however, removed by the following communication from Mr. W. Carruthers, who kindly undertook their examination, and who says, "The specimens you have sent me for examination from Rio Tinto contain the following fragments of plants which I have been able to identify:—leaves and acorns of *Quercus Ilex*, Linn.; leaves and seed of a two-leaved species of *Pinus*, most probably *Pinus Pinea*, Linn.; the cone of *Equisetum arvense*, Linn.; and a small branch of a species of *Erica*. There is also a well-marked leaf of a Dicotyledonous plant which I have not yet been able to identify. The greater portion of two of the specimens consists of a thick growth of moss, but it is impossible to say what the species are. The whole is permeated with minute branching roots, showing that the vegetation was formed as a peat-moss, the oak- and pine-leaves being carried or blown into it. The plants are evidently, all of them, the same species as are still found growing in Spain."

In addition to these fossils this deposit sometimes contains minute concretionary patches of imperfectly crystallized quartz.

Every one who examines the section extending from the Cerro Salomon across the valley of the Rio Agrio to the Mésa de los Pinos will probably agree that the origin of this deposit of iron-ore can scarcely be doubtful. At the time of its formation a marsh or shallow lake extended from beyond the last-named point to the foot of Salomon, and into this flowed solutions of iron-salts resulting from the decomposition of the upper portions of the immense masses of pyrites constituting the south lode.

From these salts oxide of iron was deposited, as in the case of bog iron-ores generally; and, finally, the valley of the Rio Agrio was eroded, as well as that south of the deposit, leaving the Mésa capped with iron-ore, while a small patch of the same mineral was left at the Cerro de las Vacas.

That the deposit took place at a comparatively recent date is evident from the fossils it contains; and it is equally certain that the erosion of the valley is older than the occupation of the district by the Romans. Not only are numerous remains of buildings and other works belonging to the Roman period found in the valleys, but the Roman grave-stones, of which scores are still scattered over some parts of the district, are invariably made of this iron-ore.

Discussion.

Mr. Carruthers pointed out that the deposit, though of such thickness and importance, was essentially a bog iron-ore and, like ores of that character, contained remains of recent plants.

The President remarked on the difference in appearance of massive hæmatites from ordinary bog iron-ores and those brought by the author of the paper.

Dr. Sorby asked if it were possible that these could have been deposits produced by springs, such as occur on the hill-sides of Yorkshire, and are still forming.

Mr. Pattison stated that the bog-ore deposits in Ireland occur on the sides and summits of hills, and that the Rio-Tinto deposit is a true bog iron-ore.

Mr. Bauerman remarked on the resemblance between this ore and that of Arklow, which is also derived from pyrites; and considered that the freedom from phosphorus was to be attributed to their rapid and direct formation as compared with ordinary bog iron-ore, which is contaminated by accessory products of decomposition from organisms and rock-masses.

The Author, in reply to Dr. Sorby, stated that the top of the deposit was regular and the bottom irregular, leading to the belief that it was probably a deposit in water. Further he indicated that there is an outlier on the same level. The hard cap is sometimes undercut by denudation. He remarked that springs are scarce over the whole district, and that there are none containing more than traces of iron in solution.

2. *On the* Constitution *and* History *of* Grits *and* Sandstones.

By J. Arthur Phillips, Esq., F.G.S. (Read December 15, 1880.)

[Plates I. & II.]

The careful and exhaustive researches relative to the constitution and mode of formation of arenaceous rocks which have recently been published by Professor Daubrée, Dr. Sorby, and others, leave open a comparatively restricted field for the pursuit of similar investigations. Having, however, during the last two years paid considerable attention to the study of rocks of this class, I now venture to bring before the notice of the Geological Society some facts and deductions therefrom which would appear to have escaped the attention of previous observers.

For the convenience of developing certain ideas relative to this subject, I propose in the present paper, in the first place, to describe various grits and sandstones which have been microscopically and otherwise examined. In doing this the older rocks will be considered first, and those of more recent age subsequently noticed in the order of their geological sequence. The chemical composition of some typical rocks will also be given.

Secondly, the results of observations bearing on the effects produced by the action of flowing water on particles of sand and gravel transported thereby will be described; and finally, the more important observed facts will be summarized, and their bearings discussed.

The difference between grit and sandstone is one not always distinctly marked; and numerous definitions of the two rocks, often somewhat contradictory, have been given by various geologists at different times. It has even been stated by an eminent authority that rocks which in the north of England would be called grits, receive the name of sandstones in the south*.

In order, therefore, to avoid misunderstanding upon this point, I may state that in the following descriptions the term grit is applied only to coarse-grained arenaceous rocks of which the component fragments are for the most part angular, and which, although frequently crystalline in structure, seldom contain either perfect or nearly perfect crystals. The cementing material of such rocks is, as a rule, highly siliceous.

Sandstones differ from grits in being finer in structure than the latter, and in their component grains being usually less completely incorporated with the cementing medium. The quartz in many sandstones occurs principally in the form of perfect crystals, or in that of crystalline aggregations.

In quartzites the spaces between the component grains are completely filled by a siliceous cement, in which respect they closely resemble some varieties of fine-grained grit.

* 'Manual of Geology,' by John Phillips, F.R.S., p. 654.

1.

x 18

2.

x 18

Frank Rutley, del.

Mintern Bros. imp.

SECTIONS OF GRITS.

Frank Rutley, del.

Mintern Bros. imp.

SAND GRAINS.

Composition and Structure.

Cambrian.—The well-known Barmouth Grits of North Wales, which occupy a large extent of country lying between Barmouth and Harlech, are usually of a greenish-grey colour. They are extremely hard, and often enclose angular fragments of quartz above a quarter of an inch in diameter. Sometimes these grits become fine-grained, and assume a purple tint; they are intermingled with occasional bands of greyish-green and bluish slates, which, especially towards the lower part of the series, attain considerable development. Of these rocks Professor Ramsay remarks:—"The beds seem to have been formed principally by the direct waste of rocks of a granitic character, or at least into the composition of which crystalline quartz and felspar largely enter"*.

When a thin section of this rock is examined under the microscope, it is seen to consist, mainly, of an aggregation of fragmentary quartz and felspar united by a siliceous cement, which is throughout permeated by a moss-like greenish mineral, a portion of which is probably chlorite. The larger pieces of quartz and felspar are often distinctly rounded, although they also sometimes present irregular and perfectly sharp outlines. Fig. 1, Pl. I., drawn by Mr. F. Rutley, represents, in black and white, a section of this rock as seen in polarized light, magnified 18 diameters, and containing much felspar.

The quartz occasionally contains liquid-cavities enclosing moving bubbles, but these are by no means numerous; the greenish mineral of the cement sometimes penetrates into fissures in the siliceous grains. Two distinct species of felspar are present in considerable quantities, the larger grains being, for the most part, somewhat rounded fragments, which, after having assumed the form of pebbles, have sometimes been broken across their smaller diameter, thus presenting one angular and one rounded termination. The orthoclase is not much altered; and a triclinic felspar, which, from the optical properties it exhibits, is probably oligoclase, shows brilliant lines of twinning when seen in polarized light. Some of the quartz encloses hair-like crystals of rutile, while calcite, magnetite, iron pyrites, and a few imperfect garnets are present in the cementing siliceous base. An analysis of this rock is given, page 21.

The grits in the neighbourhood of Harlech are usually finer in grain than the foregoing, but otherwise differ from it only in containing a few imperfect crystals of epidote.

Silurian.—Stiper Stone, from the neighbourhood of Shrewsbury, is a fine-grained and exceedingly hard sandstone, the grains of which are so closely cemented together by crystalline silica as to form a quartzite. Many of the fragments of quartz, of which this rock is mainly composed, are somewhat cloudy and are considerably rounded, while others are colourless and transparent, with but few fluid-cavities, which are, for the most part, full. The average diameter of the grains is about $\frac{1}{50}$ inch, and some of the most pebble-

* Geology of North Wales, p. 17, ed. 1.

like among them form the nucleus of a crystalline growth of colourless transparent quartz, which converts them into more or less perfect crystals of that mineral. Felspar is not abundant, and is often considerably altered; the cementing material occasionally contains minute crystals of a mineral which is probably epidote.

A grit of a grey colour, speckled with minute white points, from the neighbourhood of Aberystwith, is seen under the microscope to be composed of an almost equal amount of quartzose and felspathic grains united by a siliceous cement, everywhere permeated by a moss-like chloritic mineral, to which reference has already been made. In this rock the constituent fragments are sometimes as much as $\frac{1}{35}$ inch in length, and their angles are usually to a certain extent rounded, although they occasionally exhibit very sharp and irregular outlines. The quartz, which exceptionally contains a few needles of schorl, is colourless and transparent, containing exceedingly minute fluid-cavities, of which the majority are full, although others enclose constantly moving bubbles.

The felspar has been subjected to considerable alteration, and is not unfrequently obscured by flocculent microliths resulting from chemical re-combinations; a portion of it, however, evidently belongs to a triclinic species. In addition to the above, there are inclusions which are undoubtedly fragments of a volcanic rock of basaltic character.

The siliceous cement contains a few crystals of iron pyrites, as well as small flakes of brown and colourless mica, of which the edges are much rounded.

It is evident that some portion, at least, of the quartz constituting this grit has been derived from the disintegration of quartz-felsite (quartz-porphyry), since its general characteristics are not only similar, but it, moreover, includes the blebby masses of an amorphous ground-mass so characteristic of the quartz of such rocks.

A fine-grained foliated rock belonging to the same series, from Llangrannog, sometimes locally called a grit, of which the grains vary from $\frac{1}{500}$ to $\frac{1}{1000}$ inch in diameter, has a composition generally similar to that of the foregoing. In addition, however, it contains numerous water-worn flakes of mica, which occur chiefly in distinct bands, and which are arranged with their cleavage-surfaces parallel to the plane of foliation of the rock. The fragments of quartz, which are of a nearly uniform size, are all sharply angular, and elongated or flattened grains are rare.

An examination of sections prepared from May-Hill Sandstone, containing numerous casts of *Pentamerus oblongus*, shows that this rock is mainly composed of angular grains about $\frac{1}{200}$ inch in diameter, united by a turbid siliceous cement, suggesting the idea of its having been deposited from waters holding clay in suspension. In addition to the smaller grains, of nearly equal dimensions, there are a few fragments of, at least, four times the size above stated. These, like the smaller ones, sometimes contain a few hair-like crystals of rutile; but fluid-cavities containing bubbles are exceedingly rare.

Sandstones, or rather quartzites, of Upper-Llandovery age are developed in the Lower Lickey hills in Worcestershire. A specimen from this locality was found to be chiefly composed of much-rounded grains of quartz, having an average diameter of $\frac{1}{50}$ inch, cemented together by a growth of transparent crystalline quartz. This mode of formation is rendered evident by the circumstance of the rounded grains being frequently composed of cloudy or slightly turbid quartz, while the cementing silica is perfectly colourless and transparent. When examined in polarized light, the cementing quartz is seen to exhibit, for a certain distance around each grain, the same colour as the grain itself, and appears to have been deposited in crystalline continuity therewith. Fluid-cavities, with bubbles, are numerous in some of the grains, while others are entirely without them. Rutile and schorl are sometimes present in the form of minute crystals.

A specimen of Denbighshire grit from Pont Cletwr Yspytty, when examined, was found to consist of an exceedingly fine-grained mosaic of cementing concrete containing minute granules of quartz, and enclosing larger fragments of the same mineral, with felspar and colourless or brown mica, each grain being from $\frac{1}{50}$ to $\frac{1}{100}$ inch in diameter. Some of the quartz fragments are so traversed by the moss-like greenish mineral, often forming a constituent of the cement of sandstones, as almost to suggest the idea of their being pseudomorphs after a mineral which has disappeared. If seen in polarized light, however, they will be observed to be each made up of several distinct grains, in the fissures between which the substance referred to has obviously been deposited. The quartz of this sandstone occasionally encloses a few needles of schorl or hair-like crystals of rutile ; cavities containing bubbles are rare.

A rock belonging to the Coniston-Grit series from Green-quarter Fell, Westmoreland, consists of angular grains of quartz and felspar, united by a siliceous cement traversed in all directions by numerous greenish microliths. The average size of its constituent particles does not exceed $\frac{1}{1000}$ inch, although there are a few larger ones, measuring about $\frac{1}{50}$ inch in diameter. The quartz contains few fluid-cavities with bubbles ; but when these occur they are extremely minute. This rock contains a little iron pyrites, and the cement is sometimes stained by hydrated ferric oxide ; a few flakes of colourless and dark-brown mica are occasionally seen between the grains of quartz and felspar.

Devonian.—The majority of the siliceous grits of Cornwall are usually regarded as being of Devonian age ; but it is probable that some of them may be of older date.

Two distinct beds of such rock, of a greenish-grey colour, which are worked for road-metal, are quarried on the farms of Tregian and Dairy, in the parish of St. Ewe, near St. Austell, and were noticed in a previous paper under the name of slaty agglomerates*.

In both these localities the grit contains angular fragments of a soft clay-slate of a greenish-blue colour, and is exceedingly hard and tough. The rock quarried at Tregian is composed of a mixture

* Quart. Journ. Geol. Soc. 1878, vol. xxxiv. p. 476.

of angular pieces of quartz and felspar, of which some of the larger fragments have a diameter of $\frac{1}{10}$ inch; they are cemented by a siliceous concrete enclosing particles of granular quartz, through which minute greenish microliths are plentifully disseminated. Comparatively few fluid-cavities, either with or without bubbles, are present. In addition this rock contains a few crystals of schorl enclosed in the quartz, some water-worn flakes of silvery-white mica, a few crystals of pyrites, and perhaps a little altered magnetite. The felspar chiefly belongs to a triclinic species, but orthoclase is also present. The rock at Dairy differs from that at Tregian only inasmuch as it contains a few water-worn crystals of hornblende and a little magnetite.

In addition to the foregoing, through the kindness of Mr. J. H. Collins, I have been enabled to examine four other specimens of Cornish grit, namely, one from St. Allen, four miles north of Truro, two from Ladock, five miles further east, and one from Perranzabuloe, on the Bristol Channel.

Hand specimens of all these rocks closely resemble one another, excepting that those from Ladock enclose numerous angular fragments of a greenish slate, which the others do not, and that one of them contains a number of rounded quartzose and other grains $\frac{1}{4}$ inch in diameter.

When examined under the microscope, the St. Allen grit differs little from those at St. Ewe; the quartz is angular and transparent, the largest fragments having a diameter of about $\frac{1}{25}$ inch, and they sometimes, though rarely, enclose minute crystals of tourmaline. A little hornblende, with white mica and epidote, are also present. The felspar is, to a large extent, triclinic, but there is also some altered orthoclase; the quartz contains but few fluid-cavities.

In the rock from Ladock, which contains small rounded grains of quartz, felspar, and other material, these bodies are sparsely disseminated throughout the mass of the normal grit; and a microscopical examination shows that some of them are fragments of volcanic rocks closely akin to the "greenstones" and "dunstones" of many parts of Cornwall, but which have often become so altered as to be recognizable only by their felspars and general structure.

Fig. 2, Pl. I., represents, in black and white, a fragment of volcanic rock which occurs in this grit, as seen in polarized light, magnified 18 diameters.

The second specimen from this district is made up chiefly of angular fragments of quartz and felspar, united by the usual cementing concrete. It contains a considerable amount of felspar, a large proportion of which is triclinic. The largest pieces of quartz are about $\frac{1}{12}$ inch in diameter; and fluid-cavities, although by no means abundant, are more plentiful than they are in the Cornish grits before described. Some of the quartz contains a notable quantity of disseminated epidote (?), and flakes of white mica are frequently jammed between the fragments of which the rock is composed. A few minute garnets are present, as well as some fragments of a volcanic rock.

The microscopical structure of the gritty rock from Perranzabuloe so closely resembles that of those from the other localities that a special description of it is unnecessary. The felspar, of which a large proportion is triclinic, is present in large quantities; and, as in the case of the other specimens examined, the quartz contains but few fluid-cavities. It will be observed that in this respect the quartz of these grits materially differs from that of the Cornish granites, in which fluid-cavities with bubbles are abundant.

Carboniferous.—A fine-grained yellowish-white sandstone from Shalk Beck, Cumberland, belonging to the Yoredale series, much spotted by stains of hydrated ferric oxide, and rendered somewhat mealy by the presence of kaolin, contains but few fragments of more than $\frac{1}{150}$ inch in diameter. The quartz is in angular pieces, colourless and transparent, and, to a large extent, free from fluid-cavities, which, when present, are, for the most part, full, and consequently without bubbles. In addition to quartz, with a little felspar and kaolin, the only recognizable mineral is white mica. For the analysis, see p. 21.

A sandstone from Brigham, Cumberland, belonging to the Millstone-Grit series, was examined both microscopically and chemically, and is essentially composed of fragments of quartz with a little felspar, the grains being usually about $\frac{1}{125}$ inch in diameter, united by a siliceous cement, which is sometimes a little cloudy. Between the constituent fragments of this rock there are sometimes minute crystals of a mineral which may perhaps be epidote; and the quartz, which is colourless and transparent, encloses a few needles of tourmaline, besides containing occasional fluid-cavities, but few of which contain bubbles. For the chemical composition of this sandstone, see page 21.

At Spinkwell quarry, near Bradford, a foliated siliceous sandstone, which can be raised in the form of very large slabs, is worked in the Lower Coal-measures, and is much used in the construction of chemical apparatus on a manufacturing scale. This sandstone is mainly composed of fragmentary quartz and felspar, of the latter of which a portion is triclinic, united by the usual siliceous cement. The quartz is colourless and transparent, and contains but few fluid-cavities, although it sometimes encloses needles of schorl.

In addition to quartz and felspar, this rock contains kaolin, with a few minute garnets, and flakes of dark-brown and colourless mica, which are more abundant along certain lines of foliation than elsewhere. A few minute crystalline scales of micaceous oxide of iron were observed in the quartz of this sandstone. The component fragments rarely exceed $\frac{1}{250}$ inch in diameter. For analysis of this rock, see page 21.

The fine-grained yellowish-grey Coal-measure sandstone of Stonyhough, Workington, Cumberland, is, to a large extent, composed of minute crystals or crystalline aggregations of quartz of about $\frac{1}{200}$ inch in diameter, somewhat loosely united by a siliceous cement, often much stained by hydrated ferric oxide.

A considerable number of sandstones belonging to the Carboniferous period are chiefly composed of quartz crystals, which have evidently crystallized *in situ,* since they exhibit the freshness of outline peculiar to crystals which have not been subjected to the slightest amount of abrasion subsequently to their formation, not a point being broken or an angle removed. Sometimes the original grains of quartz have, by the subsequent deposit of silica upon their surfaces, become converted into complete double-terminated crystals; but the forms are frequently less simple, and the faces bounding the exterior cannot all be referred to the same crystal. That this crystallization is produced by a deposit of silica around the original grains of quartz, subsequently to their having become members of an accumulation of sand, was first noticed in British rocks by Professor Bonney *, and has been subsequently demonstrated by Dr. Sorby †. It is almost equally certain, as will be subsequently shown, that a portion, at least, of the silica so deposited has been derived from the decomposition of felspar.

Among highly crystalline Carboniferous sandstones may be mentioned one belonging to the Mountain-Limestone series, which occurs at Yeathouse, in Cumberland, that of Parkhead, in the same county, and that of Augill, near Brough, Westmoreland; the two last of Yoredale age. Another sandstone in the Lower Coal-measures, worked at Barngill quarry, in the county of Cumberland, is also crystalline.

Permian.—The St. Bees Sandstone, at Rheda, Cumberland, is a fine-grained reddish-brown rock, composed of a mixture of angular fragments and minute crystals of quartz with a little felspar, the whole being united by a cement rendered, to some extent, opaque by ferric hydrate. The grains and crystals of quartz have usually a diameter of about $\frac{1}{200}$ inch, and contain but few fluid-cavities. The colour of this sandstone, like that of the majority of similar rocks, is caused by a coating of hydrated oxide of iron over the surfaces of the grains and crystals of which it is composed, but which is readily removed by digestion in acids. Felspar is present in notable quantity, and is often considerably altered; no triclinic species was observed. A small amount of colourless mica is present in the form of water-worn flakes, together with a few imperfect crystals of schorl.

Numerous other crystalline sandstones of Permian age might be cited; but those of Penrith, which have been described by Dr. Sorby, are probably the most interesting and remarkable examples.

Triassic.—Among the Bunter sandstones of Lancashire and Cheshire are certain reddish-brown friable beds, possessing but little cohesion, and of which the constituent grains are all so completely rounded, that the disintegrated sand flows between the fingers as readily as shot. Deposits of such sandstones, which are distinguished by the name of "Millet-seed beds," occur plentifully in the Lower Mottled series, and occasionally among the Upper Mottled sandstones, as well as in the Frodsham beds of the Keuper.

A specimen of millet-seed sandstone from the Lower Bunter, obtained in the form of a core, at a depth of 1039 feet, from the

* Quart. Journ. Geol. Soc. vol. xxxv. p. 666.

† Address delivered at Anniversary Meeting of the Geological Society of London, 20th February, 1880, p. 36.

Bootle bore-hole of the Liverpool water-works, was, with a large number of others from that district, kindly furnished to me by Mr. Charles E. De Rance, of the Geological Survey, but was found to be too friable to admit of the preparation from it of thin sections. On examination by reflected light, however, it was found to be so entirely made up of rounded grains, varying in diameter from $\frac{1}{50}$ to $\frac{1}{200}$ of an inch, that I did not hesitate to suggest to Mr. De Rance the probability of its origin being due to blown sands united by a ferruginous cement.

These grains, of which the majority are quartz, are so rounded as to represent miniature pebbles, while a few, consisting of partially decomposed felspar, are often corroded into deep cavities on one or more of their sides.

The granules of quartz, as well as those of felspar, have been covered by a thin coating of hydrated ferric oxide; while on the surfaces of the former a beautiful growth of crystals of transparent quartz has frequently taken place.

These crystals do not often exceed $\frac{1}{100}$ inch in length; but they are sometimes very perfect, with sharply defined angles, and frequently exhibit both plagihedral modifications and horizontal striation. A few crystals of pyrites and of calcite have also been formed on the surfaces of the rounded quartz-grains.

Figs. 1, 2, 3, and 5, Pl. II., drawn by Mr. F. Rutley from specimens which I selected for that purpose, and magnified one hundred diameters, represent crystals of quartz attached to rounded grains of the same mineral forming the basis of this sandstone. Fig. 4, magnified to the same extent as the others, is a grain of quartz which exhibits a depression at its point of contact with another similar body. Specimens presenting this appearance, which are not very numerous, may sometimes be the result of one grain of quartz having been forced or ground into the substance of another. A careful examination, however, of such depressions leads to the conclusion that in some cases when this pitting of a grain is observed a deposit of silica may have taken place upon all parts of its surface, excepting where it has been protected by contact with adjoining grains.

Angular cores of a siliceous material which have been deposited in cavities at the point of junction of several grains are sometimes detached when the rock is carefully disintegrated by friction with a hard brush. When these adhere to one only of the adjacent grains, having separated from the others, they obviously might give rise to depressions of the kind referred to.

If, after treating this sandstone by hydrochloric acid, the residue be examined under the microscope, the presence of these siliceous bodies becomes at once apparent. They are sometimes slightly coloured by ferric oxide, and do not always exhibit colours when seen in polarized light; in other cases they afford evidence of imperfect crystalline structure, and are occasionally colourless and transparent.

Fig. 6, Pl. II., is a grain of felspar which has become so corroded that two distinct cavities have been produced in its substance. A crystal of iron pyrites attached to a rounded grain of quartz is seen in fig. 7, which, as well as the preceding figure, is represented as magnified to the same extent as the other illustrations contained in the Plate.

Prolonged digestion in hydrochloric acid removes the oxide of iron, leaving the surfaces of the rounded quartz granules clean and colourless. The minute crystals of quartz which have been formed upon them, however, adhere firmly to the rounded grains, after this treatment, and no stain of ferruginous matter can be observed between their point of attachment and the grain of sand on which they have been formed. It would therefore appear that, although the sand had been covered generally by ferric hydrates previous to the growth of quartz crystals, these have nevertheless originated at those points only where a chemically clean surface of the quartzose nucleus was exposed. An analysis of this sandstone is given, p. 21.

Sandstones chiefly composed of rounded weather-worn grains occur in the Lower Mottled series, at a depth of 80 feet from the surface at Stock's Well, belonging to the Widnes water-works, and at Scott's bore-hole near St. Helens, as well as at a depth of 260 feet in the Winwick boring of the Warrington water-works.

Beds of loose, rounded sand of the age of the Lower Mottled Sandstone are known to occur at Chapel Bridge, Prescot, and in a boring a little east of Newton Bridge, near Warrington.

Sandstones of this character are met with north of Eccleston hill, and a similar bed belonging to the Upper Mottled group comes to the surface in the yard of the Bridgewater Foundry at Runcorn. By no means, however, do all the sandstones of Lancashire and Cheshire which belong to this geological age exhibit characteristics suggestive of their formation from æolian sands. At Wirral, in Cheshire, as well as sometimes in the neighbourhood of Liverpool, the Pebble-beds of the Bunter are represented by a brownish-yellow sandstone containing numerous pebbles, which is much employed for building-purposes.

In many of these beds the quartz is almost entirely in the form of minute crystals, or crystalline aggregations, often united by a ferruginous cement, which has manifestly been introduced subsequently to the covering of the original grains with crystalline quartz. An excellent example of a non-ferruginous crystallized sandstone belonging to the Upper Mottled group occurs at Town Green, near Ormskirk. This rock is mainly composed of crystals of transparent quartz, of which the edges and angles are beautifully perfect. It is of a far too friable nature to allow of the preparation of thin sections; but it appears to have little or no cementing material, and to be, to a large extent, merely felted together by the intergrowth of its constituent crystals. It will be needless to remark that the grains of sandstones of Bunter age are not always either rounded or enveloped in crystals of quartz.

Among the Keuper division of the Triassic sandstones, which are mainly composed of well-rounded siliceous grains, may be cited a grey, friable, fine-grained rock from the base of this formation, which is exposed in the railway-cutting at the Runcorn station, and a dark-red sandstone of still finer texture, belonging to the Frodsham beds, at no great distance from the same locality. The Lower Keuper cupreous sandstones of Alderley Edge, Cheshire, are frequently made up of quartz crystals on which still more minute crystals of *vanadinite* may sometimes be distinguished by the aid of a lens.

In many localities the quartz pebbles occurring in crystalline arenaceous rocks have their surfaces, and more particularly their upper surfaces, covered by minute crystals of that mineral. This may be observed in the case of pebbles found in Lower Keuper sandstone in a quarry near Litherland.

At Dymoke, Worcestershire, there is a Lower Keuper sandstone which is sufficiently coherent to admit of the preparation of thin sections. This is a fine-grained, quartzose, distinctly laminated rock, of which the component grains are usually about $\frac{1}{250}$ inch in diameter. These to a large extent consist of quartz, sometimes enclosing hair-like crystals of rutile, and occasionally fluid-cavities, in some of which bubbles were observed. A certain amount of felspar, a portion of which is triclinic, is present in this rock. A few flakes of colourless mica, and a little of the fibrous mineral which has been referred to as often occurring in the cement of certain sandstones, were also observed. The cementing material, which contains a little kaolin, encloses a few minute garnets, and is frequently stained by hydrated ferric oxide.

The Waterstone beds belonging to this series enclose numerous angular fragments of dark-coloured slaty rock, some of which are as much as $\frac{1}{2}$ inch in diameter. The quartz grains, many of which are $\frac{1}{15}$ inch in diameter, are usually much rounded, and not unfrequently enclose fluid-cavities. In addition to quartz and the cementing material felspar is present, as is also, in small quantities, another mineral of a light yellowish-green colour, which I have been unable to identify, but which occasionally forms part of the cement.

A fine-grained sandstone of Upper Keuper age, which occurs at High House, Warwickshire, is to a large extent composed of quartz crystals, while a bed of loose sand, found 25 feet below the surface at Frodsham, above the Keuper Marl, is, on the contrary, entirely made up of much-rounded grains.

The rounded quartz grains of Triassic sandstones, when examined in a suitable medium, after the removal of their external ferruginous coating, are found to be colourless and often transparent. Grains containing fluid-cavities are comparatively rare, but they are apparently more numerous in the Keuper sandstones than in rocks of Bunter age. A few crystals of schorl occasionally present themselves in the quartz of these rocks, which is not unfrequently rendered turbid by the enclosure of what is probably a little ferruginous clay. It is, however, probable that the grains containing fluid-cavities in which crystals of schorl are also found owe their origin to a different source from that whence the supply of quartz which does not contain such cavities was derived.

Jurassic.—A fine-grained Upper Lias sand, of a greenish colour, from Seizincote, Stow-on-the-Wold, Gloucestershire, effervesces when treated with hydrochloric acid, leaving grains of transparent quartz, which are generally angular. In some instances, however, their more acute angles appear to be slightly rounded, although the mean diameter of the fragments is only $\frac{1}{200}$ inch. Besides quartz containing occasional fluid-cavities, usually without bubbles, there are present a few pieces of somewhat doubtful felspar, together with numerous fragmentary crystals of schorl and garnet.

The only coherent arenaceous rock of this age which I have had an opportunity of examining is that quarried at Egton, near Whitby, under the name of "Moor Grit," which is locally much employed for road-metal. It is white and fine-grained, being often so compact as to be entitled rather to the name of quartzite than to that of grit. Its geological horizon is above the Grey Limestone in the estuarine series of the Lower Oolite in North-east Yorkshire.

Under the microscope this rock is seen to be almost entirely composed of transparent, colourless quartz, of which the largest pieces are about $\frac{1}{75}$ inch in diameter, and of which the angles are usually more or less removed. Around and between these grains a deposit of transparent crystalline quartz has taken place, thus forming a cementing medium. A few small garnets are present, but no fluid-cavities with bubbles were observed, although some of the quartz encloses minute crystals of a yellowish mineral which I have been unable to identify; these are exceedingly minute, often not exceeding $\frac{1}{10000}$ inch in length. Many of the smaller grains in this rock exhibit, when examined in polarized light, that complex structure so frequently observed in the quartz of clay-slates and other somewhat similar rocks.

A sand resulting from a disintegrated Portland Stone at Fonthill Giffard, Wiltshire, is largely composed of ovoid grains of calcite. After being attacked by hydrochloric acid, a rounded quartzose sand, amounting to about one quarter of the total bulk of the mixture, remains behind. This sand, of which the grains vary from $\frac{1}{70}$ to $\frac{1}{250}$ inch in diameter, contains but few fluid-cavities, and these, as a rule, are without bubbles. The fragments of quartz are associated with, and not enclosed by, the ovoid grains of calcic carbonate.

Cretaceous.—The Tilgate Sandstone, Ashdown Sands, from Newick Park, Sussex, is composed of slightly rounded grains of colourless transparent quartz, united by a cement consisting partly of calcic carbonate and partly of flint. The quartz is almost entirely free from fluid-cavities, but encloses a few hair-like crystals of a mineral which is probably rutile. If felspar be present it has become too extensively altered to admit of identification.

Sections have been examined of the chert known as Sevenoaks Stone, as well as of several others of Lower Greensand age. They all contain numerous fossils, particularly sponge-spicules, and in some cases consist, to a large extent, of amorphous silica; in others the rock becomes crystalline and distinctly chalcedonic. The flinty varieties often contain crystals of calcite, which cluster around an included fossil as a nucleus. All the specimens examined contain glauconite, and occasionally grains of ordinary quartz, some of which are much rounded, while others are angular.

The "Carstone" of Hunstanton, near King's Lynn, Norfolk, and of various other localities, is a friable ferruginous sandstone belonging to the upper portion of the Lower Greensand formation, and occurring in beds of which the relations have not, as yet, been accurately determined. A series of specimens from this locality was kindly furnished me by Mr. S. B. J. Skertchly, of the Geological Survey, who is at present occupied in working out the geology of the district. With the exception of certain variations in colour, these beds so closely resemble one another in their general characteristics that a description of one of them will suffice for the present purpose.

A specimen of Carstone from immediately below the Red Chalk exposed in the cliff at Hunstanton was found to be mainly composed of a mixture of somewhat rounded grains of quartz, with small pebble-like granules of dark-brown iron-ore. The individual grains of these minerals vary in diameter from $\frac{1}{10}$ inch to the most minute sand, although small pebbles of larger size than the highest limit quoted are not of unfrequent occurrence. The quartz contains schorl and rutile, together with a few fluid-cavities, of which the majority are without bubbles. In addition to ordinary quartz grains, this rock, when carefully disintegrated, exhibits numerous examples of the angular bodies resulting from the breaking-up of a siliceous deposit formed between the grains of the original sand, which have been noticed (p. 13) in connexion with millet-seed sandstones of Bunter age.

By the prolonged action of hydrochloric acid the quartz of this rock is rendered colourless, while the globules of ferric hydrate are dissolved, with the exception of a siliceous skeleton which preserves the exact form of the original grains. These bodies do not usually exhibit colours when mounted in balsam and examined by polarized light; but in a few cases the presence of a dark cross indicates a pisolitic structure in the siliceous residue*. In addition to the foregoing, this rock contains a few minute scales of mica and a very small quantity of felspar. The majority of the grains of quartz have their angles distinctly abraded; in some instances they have been completely removed, and a pebble-like form has been the result.

A specimen of Carstone obtained from a bed directly beneath the Red Chalk, afforded on analysis the following results:—

* Both Dr. Percy and Professor Judd have described siliceous skeletons which occur in the pisolitic grains of Northamptonshire iron-ore:—Metallurgy, Iron and Steel, pp. 225, 226; Memoirs of the Geological Survey, Geology of Rutland &c. p. 119.

Water { hygrometric	3·85
Water { combined	6·56
Silica	49·81
Phosphoric anhydride	0·42
Alumina	5·17
Ferric oxide	29·17
Ferrous oxide	0·35
Lime	2·43
Magnesia	0·95
Potassa	0·48
Soda	0·84
	100·03

Another variety of this rock from the same locality, but darker in colour, was found to contain 37 per cent. of ferric oxide and 45 per cent. of silica; the amount of phosphoric anhydride was nearly the same as in the first specimen analyzed.

An examination of the spherules of various pisolitic iron-ores shows that they exhibit all the characteristics of the globular ferruginous grains found in these sandstones; and it may therefore be inferred that they have had a similar origin. A pisolitic iron-ore of Middle Neocomian age, which occurs at Market Rasen in Lincolnshire, consists to a large extent of spherules very closely resembling the ferruginous grains in the sandstones at Hunstanton.

Tertiary.—Hertfordshire Puddingstone, Lower Eocene, is a conglomerate of flint pebbles united by a concrete consisting of fragments of transparent quartz and greyish flint held together by a flinty cement. In this concrete the quartz is considerably in excess of the flint, and sometimes contains fluid-cavities. Its fragments are all angular, and vary in diameter from $\frac{1}{75}$ to $\frac{1}{250}$ inch.

A specimen of sand from Hordwell, Hampshire, equivalent in age to the Headon beds, contains no recognizable felspar. All the quartz down to a diameter of $\frac{1}{75}$ inch is completely rounded; and even the smallest particles have had their angles entirely removed. Fluid-cavities with bubbles are abundant in some of the quartz constituting this sand.

Sand from the Marine beds, near the top of the Hempstead series, Isle of Wight, was, after treatment with hydrochloric acid, found to be composed chiefly of grains of quartz, of which about three fourths had a diameter of less than $\frac{1}{50}$ inch. These, down to the finest particles, are much rounded, although still roughly retaining the form of the original fragments.

The fine-grained brilliantly coloured sands at Alum Bay, Isle of Wight, of Upper Eocene age, usually classified as Lower Bagshot, have not, as yet, been definitely identified with the beds of the London Basin. By digestion in hydrochloric acid the quartz becomes colourless; and, although not completely rounded, the angles even of the smallest fragments have generally been modified by attrition. Fluid-cavities are not plentiful, and when present seldom enclose bubbles.

Needle-like crystals of schorl are sometimes enclosed in this quartz.

The most considerable bed of sand at Bovey Heathfield, Devonshire, no. 27 of Mr. Pengelly* (Miocene?), consists largely of quartzose fragments, nearly all of which are sharply angular, transparent, and colourless. They contain fluid-cavities with bubbles; but the latter appear to be less numerous than in the quartz of some Cornish granites. Schorl is present in considerable quantity, both as detached crystals and as portions of crystals, also as needles penetrating quartz.

Post-Tertiary.—Sand washed from the Lower Boulder-clay at Holywell, Flintshire, is largely composed of small quartz pebbles, rounded grains of various felspathic and other rocks, and numerous fragments of millet-seed sandstone. A few unworn quartz crystals resulting from the disintegration of crystalline sandstones, and some angular grains of quartz, were also observed. Even the smallest particles of this sand are often rounded.

The larger grains of a sand of Middle Glacial age which occurs in this locality are either rounded grains of quartz or of some other rock, or small pebbles of millet-seed sandstone. Those of medium size are millet-seed quartz grains, mixed with a few unworn crystals and angular pieces of the same mineral.

A specimen of Middle Glacial sand from Bagilt in the same county differs in no respect from the foregoing, excepting that crystals of quartz derived from crystalline sandstones are rather more numerous, angular fragments are less rare, and broken millet-seed grains are of more frequent occurrence.

The Middle Glacial drift at Colwyn Bay is mainly composed of small pebbles of various rocks, principally of quartz, with a few unworn crystals of the same mineral, resulting from the disintegration of sandstones. In this drift the smallest fragments, although generally rounded, have not been converted into minute pebbles.

At different times I have examined numerous specimens of recent water-borne sands. Among these, that on the sea-shore at Pentewan in Cornwall is, as described, p. 24, perfectly sharp and angular, as is the sand on the beach at Par, about six miles further east. According to Dr. Sorby such is also the case with regard to the sands of the modern beach at Scarborough, and those of the river-terraces at Dunkeld.

A large proportion of the quartz in the sands of the Thames valley is sharply angular, although mixed with rounded grains of the same size. The grains of the auriferous sands collected on the coast of Northern California are likewise for the most part angular, although perfectly rounded ones are at the same time present.

Among the blown or æolian sands which have been examined is one from the Great African Desert, and another from Arabia Petræa. The grains of these are, without exception, much worn; and there is no admixture of the angular fragments found in

* "The Lignites and Clays of Bovey Tracey," Phil. Trans. 1862, vol. clii. p. 1019.

all subaqueous deposits; the majority are in the state of minute well-rounded pebbles. As in the case of water-borne sands, the effects of attrition are more conspicuous in the larger fragments than in the smaller ones; but even the most minute particles are in these sands much rounded. Exceptionally the quartz encloses fragments of a felspathic material; and fluid-cavities with bubbles are not entirely absent in African specimens.

A bed of sandstone, said to occur in a salt-producing district sixty miles south-east of Tebessa, of which some years ago I brought a specimen from Tunis to London, is entirely made up of rounded grains. In that respect this rock resembles the millet-seed sandstones of Lancashire and Cheshire; but it is unlike them, inasmuch as no crystals of quartz, or of any other mineral, have been deposited upon the surfaces of the rounded granules.

Modern blown sands, of which we have numerous examples in this country, differ from desert sands and from those of certain sandstones only in being usually somewhat less completely rounded. Among the sands of this description which have been examined are specimens from the dunes at Rhyl, Flintshire, Colwyn Bay, Denbighshire, Lytham, Lancashire, and from Perranzabuloe and Lelant, in Cornwall. Speaking generally, the sands from the northern localities have been more completely rounded than those from Cornwall, and consist of a mixture of worn quartz and various slaty and other rocks, with a little felspar and a few fragments of shells. Fluid-cavities with bubbles are rare in the quartz of these sands. In addition to rounded grains of various slaty and other rocks, quartz, felspar, and fragments of shells are present; among these quartz largely predominates. The Cornish sands contain a few partially rounded prisms of tourmaline.

Chemical Composition of Sandstones &c.—A microscopic examination of a large number of sections of grits and sandstones having led to the conclusion that many of the published analyses of such rocks must be of a very imperfect character, five different specimens were selected for analysis.

In making these analyses I have received the valuable assistance of Mr. E. W. Voelcker, A.R.S.M.; and in each case fusion with alkaline carbonates was adopted. The estimation of alkalies was made after an attack by hydrofluoric acid, and was checked by a fusion with carbonate of calcium and chloride of ammonium.

*Analyses**.

	I.	II.	III.	IV.	V.
Water { hygrometric	·125	·150	·050	·400	·150
Water { combined	·935	·700	1·290	·850	·300
Silica	80·600	75·750	87·400	85·550	87·150
Alumina	9·200	8·227	3·997	7·570	3·948
Carbonic anhydride	1·025	....	1·876	....	1·200
Phosphoric anhydride	·076	0·15	trace.	·070	trace.
Sulphuric anhydride	trace.	·171	·060	trace.	·094
Ferric oxide	trace.	10·521	....	....	1·352
Ferrous oxide	2·370	1·352	1·366	1·915	
Ferric persulphide (FeS_2)	....	....	·300	·753	·203
Manganous oxide	·232	trace.	·279	....	
Lime	1·330	·532	1·932	·588	2·681
Magnesia	1·285	·360	·684	·612	1·080
Potassa	1·647	1·059	·741	·915	1·273
Soda	1·372	1·283	·332	1·113	·840
	100·197	100·120	100·307	100·336	100·271
Specific gravity	2·689	2·464	2·710	2·531	2·660

I. Grit, Cambrian: Barmouth, North Wales.
II. Sandstone, Carboniferous†: Yoredale Series, Shalk Beck, Cumberland.
III. Sandstone, Carboniferous: Millstone-Grit Series, Brigham, Cumberland.
IV. Sandstone, Carboniferous: Lower Coal-measures, Spinkwell quarry, Bradford.
V. Sandstone, Triassic: Bunter, Bootle Well, Liverpool.

Examination of Water-borne Sands.

With the view of to some extent studying the action of running water upon the mineral fragments which it transports, a microscopical examination was made of the sands of the St. Austell river, in Cornwall. This stream, which during the summer months is a mere rivulet of moderate size, sometimes in winter becomes a considerable torrent. Its eastern arm arises at a distance of two miles and three quarters from the town, and at a height of 470 feet above the foot of the weir at the "Old Bridge." Its western arm, which meets the other a little north-west of the town, takes its rise in a small valley only a mile from the point of origin of the more easterly branch. From the bridge the distance to the sea at Pentewan is four miles, while the total fall is only 114 feet.

This stream formerly carried with it into the bay vast quantities of the granitic sand which is separated by washing from china-clay at the different clay-works in the district. As, however, catch-pits have of late years been employed for the purpose of retaining it at

* Since the above were completed, my attention has been directed to some analyses published in U. S. Geol. Survey, XLth Parallel, vol. ii. pp. 35 & 246, which agree very closely with those here given.

† A white fine-grained sandstone, much spotted with brown.

the several works, the quantities thus transported are now very small.

On the eastern branch a certain amount of granitic sand escapes into the stream almost immediately at its source; this is repeated at short intervals for a distance of a mile and a half, and finally ceases a mile and a quarter above the Old Bridge, at a height of about 200 feet above the weir-foot.

The first introduction of sand into the western branch takes place nearly a mile below its source, and is discontinued half a mile further down its course, but at a somewhat lower level than in the case of the eastern fork.

It follows that, before arriving at the bridge, each grain of sand must have travelled over a distance of at least a mile and a quarter, with a fall of above 150 feet, while a portion of it has been transported two miles and three quarters through a channel thickly strewn with granite boulders, and having a fall in that distance of 470 feet.

Before arriving at the sea, therefore, the whole of the sand must have travelled at least five miles and a quarter, with a minimum fall of about 270 feet, while a portion of it will have been transported a distance of six miles and three quarters over a total declivity of 584 feet.

The first samples of material were collected from the bed of the river a little below the bridge, and a mile and a half from the point at which the last granitic sands are discharged into the stream.

For the purpose of facilitating a microscopical examination of these sands, they were divided into four different parcels by a series of sieves, the first sieve allowing to pass through it all fragments less than $\frac{1}{40}$ inch in diameter, the second those having a less diameter than $\frac{1}{80}$ inch, and the third all particles having a smaller diameter than $\frac{1}{160}$ inch.

The largest fragments, retained upon the coarsest sieve were about $\frac{1}{4}$ inch in diameter, graduating to a diameter of $\frac{1}{40}$ inch.

This sand consists of a mixture of quartz, felspar, schorl, and mica, in which the last-named mineral is present in smaller proportion than any of the other minerals. When examined by reflected light, and magnified 20 diameters, the edges and points of the different fragments of quartz and schorl are found to be sharp and unrounded; the only exception being in the case of certain grains of quartz, which Dr. Sorby suggests may have been corroded by the action of alkaline waters, but which may have perhaps never possessed other than rounded outlines.

The angles and edges of the felspar and mica are, on the contrary, distinctly rounded; and although this might have been anticipated as regards the mica, it is at first sight not so easily understood in the case of felspar, whose density and hardness differ but slightly from those of quartz. It must, however, be remembered that the grains of felspar had become externally kaolinized while still forming an integral portion of the decomposed granite, and that, on the removal of this coating of china-clay by washing, a rounded central nucleus will remain.

Sand which had passed through the $\frac{1}{40}$-inch apertures of the first sieve, but which was retained by the $\frac{1}{80}$-inch openings of the second, has a similar composition to that of coarser grain. The quartz and schorl are both angular; the felspar is more rounded than the quartz; and the mica, which is more plentiful than in the coarser sand, is much worn on the edges.

The sand, which after passing through the $\frac{1}{80}$-inch sieve was retained on the $\frac{1}{160}$-inch sieve, consists of a mixture of angular quartz, unworn crystals of tourmaline, grains of felspar (some of which are rounded) and flakes of mica (which are much worn on the edges).

An examination of the material which passed the sieve having apertures $\frac{1}{160}$ inch in diameter, shows that its grains are entirely unwaterworn. The proportion of mica is much larger than in the coarser sands, and there is less felspar; but most of the grains have had their angles removed. The quartz is generally in the form of tabular flake-like fragments, while the schorl often occurs as small acicular crystals.

The quartz of these sands is frequently penetrated by needles of schorl; and when mounted in balsam it is seen to be full of fluid-cavities containing bubbles—in this respect differing entirely from the quartz of the Cornish grits, as well as from that of the majority of sandstones.

Specimens of the sandy deposit were taken from down the course of the river, at intervals of a mile apart, the last having been obtained at a point slightly above the sea-level at high water at Pentewan. In every case, however, they so exactly resembled those first taken from below the Old Bridge at St. Austell as not to require detailed description. The quartz and schorl are angular, the felspar is more or less rounded, and the larger flakes of mica are worn at the edges. With regard to the distribution of sand along the river-bed, it is needless to remark that the coarser fragments are found towards the centre of the stream, while the finer silt, with minute flakes of mica and quartz, accumulates in less rapidly moving currents near the banks.

Having found that quartz grains below $\frac{1}{40}$ inch diameter are not in the slightest degree rounded by a minimum transit of five miles and a quarter down the course of the stream, it was thought desirable to ascertain the effect of a prolonged action of the waves upon the sand lying on the sea-shore.

It must be here remarked that since the first opening of china-clay works in this district, now about sixty years since, millions of tons of granitic sand have been carried into the sea by the streams into which it was discharged. The effect of this at Pentewan has been to silt up the harbour to a very serious extent; while the whole of the sands upon the sea-beach bear evidence of having been derived from the same source.

The point from which the specimens were taken for examination is situated at a distance of half a mile west from the present mouth of the stream by which the sands were brought down. They were collected from the water's edge at half-tide; and as the discharge of granitic sands into the river has been very small during the last ten or twelve years, and this point is considerably removed from its mouth, it is evident that a large proportion of the grains taken must have been subjected during many years to the wearing action of the waves.

An examination of this sand shows that quartz having a diameter between $\frac{1}{20}$ and $\frac{1}{50}$ inch is usually angular, although some of the larger pieces are distinctly (but not considerably) rounded. The schorl, like the quartz, generally presents sharp angles, although somewhat abraded grains of this mineral are occasionally met with. Nearly all the felspar is rounded to a considerable extent, as is also the small quantity of mica which is present.

Below $\frac{1}{50}$ inch in diameter the angularity of the fragments of quartz and schorl is perfect, with the exception of occasional "corroded" grains; the felspar has, for the most part, rounded outlines; and mica is almost entirely absent.

At page 32 of his Address to the Geological Society of London (1880) Dr. Sorby remarks:—"Unfortunately I am not acquainted with sufficient facts to prove how long it would require to thoroughly wear down and round a grain $\frac{1}{100}$ inch in diameter. It is evident it is a very different thing from the wearing of a pebble, and may require a longer period of wear than we might suspect, if we did not bear in mind that when buoyed up by water the friction of such small particles on the bottom must be always small." Again, at page 34, he says:—"It appears to me sufficiently proved that a great amount of drifting and mechanical action must be required to wear down angular fragments of quartz into rounded grains $\frac{1}{100}$ inch in diameter, which I have taken as the standard for comparison."

Professor Daubrée states that the diameter of grains capable of floating in slightly agitated water is about $\frac{1}{10}$ millimetre, or, say, $\frac{1}{250}$ inch, and remarks that all smaller grains must of necessity remain angular*. He subsequently says that a current or wave capable of carrying off in suspension particles of that diameter, without in any way affecting their form, would cause larger fragments of the same mineral to so rub one against another as gradually to produce rounded sand. According to an experiment quoted by this author, a sand of which the grains have a diameter of $\frac{5}{10}$ millimetre, say $\frac{1}{50}$ inch, to which a movement of one metre per second is imparted, becomes rounded, with a loss equal to $\frac{1}{10000}$ of its weight per kilometre traversed.

This experiment appears to indicate that a grain of quartz $\frac{1}{50}$ inch in diameter requires, before becoming completely rounded and assuming the form of a miniature pebble, an amount of abrasion equal to that which would result from having travelled a distance of three thousand miles. In arriving at this conclusion the fact must not be lost sight of that, after the first rounding of the

* Géologie Expérimentale, p. 256.

angles and edges, the operation will gradually become slower as the surfaces become more worn and the weight of the grain decreases.

That angular fragments of quartz having a diameter of less than $\frac{1}{50}$ inch remain unrounded by the continuous action of breakers after many years' exposure, is evident from an examination of the sands at Pentewan. It has been shown by other evidence, as well as by the recent experiments of Professor Daubrée, that the rounding-down of such sands by the action of running water must be an exceedingly slow operation, and one requiring a somewhat active current with an amount of friction equivalent to transport over enormous distances. Grains of quartz of similar dimensions are, in blown sands, completely rounded.

Summary and General Conclusions.

The Cambrian grits of Barmouth contain quartz and felspar, both in the form of angular fragments and also as rounded pebbles. The materials presenting these different forms have probably been derived from two distinct sources; while the large size and complete sharpness of the angles of many of the irregular grains appear to indicate that they cannot have been transported from any considerable distance, and that the felspar cannot have been derived from kaolinized granite.

All the arenaceous rocks of Silurian age which have been examined contain a small proportion of felspar, the grains of the various constituent minerals being in some cases angular, and in others rounded.

Many of the rocks belonging to this period are composed of a mixture of grains of both forms. Among rocks mainly composed of rounded grains are the Stiper Stones of Shropshire and the Lower Lickey Quartzites of Westmoreland. Some of the grits from the neighbourhood of Aberystwith enclose fragments of a volcanic rock of doleritic character.

The grits of Cornwall, which are of at least Devonian age, include flakes of soft slaty rocks, the edges of which are perfectly sharp, together with angular fragments of the well-known "greenstones" and "dunstones" of that county.

A large number of the Carboniferous, Permian, and Triassic sandstones are composed almost entirely of quartz crystals, which have undoubtedly been produced *in situ*, as they not only penetrate and interpenetrate one another, but also exhibit the most perfect sharpness and freshness of outline. As confirmatory of this hypothesis it may be mentioned that in a quarry at Foggen Tor, on Dartmoor, the felspar has in places become decomposed into soft kaolin, in which the liberated silica is imbedded in the form of aggregations of well-formed and transparent quartz crystals *. Unworn double-pointed crystals of quartz, likewise resulting from the decomposition of felspar, have recently been found near St. Austell, Cornwall, in soft china-clay; one of these, more than three

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 9.

inches in length, is now in the collection of the Museum of Practical Geology. Sandstones of this description are not unfrequently without any kind of cementing matrix, being merely felted together by a matted intergrowth of their constituent crystals.

Professor Daubrée entertains the opinion that crystalline sandstones frequently owe their origin to chemical agencies resulting from an outpouring of igneous rock; but, although this may sometimes have been the case, many of the most completely crystalline British sandstones are situated at distances of many miles from any known rock belonging to this class. The same author maintains that the presence of anhydrous ferric oxide in sandstones affords evidence of their having been subjected to a high temperature*. It must, however, be remembered that the carnallite of Stassfurt, which has evidently never been highly heated, contains crystals of specular iron-ore.

Numerous fine-grained sandstones, particularly among those of Triassic Age, are composed of quartz grains so completely rounded as, under the microscope, to resemble well-worn pebbles. These "millet-seed" sandstones are often coloured either red or brown by variously hydrated oxides of iron; and in some cases minute, perfectly formed, and beautifully transparent crystals of quartz have been developed upon their surfaces.

On attacking the sand of such sandstones with hydrochloric acid, the oxide of iron is easily removed, but the crystals of quartz still remain firmly attached to the surface of the grains upon which they have grown. It would also appear that crystals have been formed upon those parts only of the grains which, having been free from a coating of oxide of iron and from every other extraneous material, have admitted of direct chemical contact between the silica of the rounded quartz and that of the subsequently formed crystals †.

In addition to silica in the form of perfect crystals of quartz, that substance has often been deposited in such a way as to fill cavities existing between the original grains of sand.

As this silica has frequently been thrown down upon a thin deposit of ferric hydrate, it is generally detached by prolonged digestion in hydrochloric acid, by which the intervening ferruginous coating of the grains is ultimately removed. When such a deposit of silica adheres to only one of the adjoining grains it may give rise to a depression upon its surface of the kind represented in fig. 4, Pl. II.

On examining a considerable number of modern sands, none of them, excepting such as had long been subjected to the wearing effects of wind action, were found to resemble those of the millet-seed sandstones in having all their grains reduced to a pebble-like form. Among these the grains of blown desert-sands most completely resemble those of millet-seed sandstones.

* Géologie Expérimentale, pp. 226–230.

† With regard to the Torridon Sandstones of the Central Highlands it has been observed by Professor Bonney that wherever "dirt" has been deposited upon the siliceous grains their agglutination has been prevented (Quart. Journ. Geol. Soc. vol. xxxvi. p. 106).

The above facts would appear to render it probable that the rounded grains of these sandstones may be of æolian origin, and that, during certain periods of Triassic time, desert areas with blown sands extensively prevailed in this country.

Mr. De Rance has observed that the millet-seed beds are usually free from pebbles, shale-beds, pseudomorphs after common salt, and from all traces of life*—conditions which are characteristic of deposits produced by wind-currents.

The granules of brown iron-ore which are so plentiful in the "Carstones" of Hunstanton are pisolitic grains, and not fragments of that mineral rounded by attrition.

An instructive example of the occurrence at the same time of rounded and angular grains is met with in the Interglacial sands of Flintshire, where some of the pebbles are fragments of a millet-seed sandstone, while many of the smaller particles are grains detached from the same rock.

EXPLANATION OF PLATES I. & II.

Plate I.

Magnified 18 diameters.

Fig. 1. Group of felspar crystals in Cambrian Grit. Polarized light: p. 7.
2. Grit from Ladock, Cornwall, enclosing a fragment of a volcanic rock. Polarized light: p. 10.

Plate II.

Magnified 100 diameters.

Figs. 1, 2, 3, & 5. Crystals of quartz deposited upon rounded grains of the same mineral in Bunter Sandstone: p. 13.
4. Depression in a grain of quartz from the same sandstone.
6. Corroded grain of felspar from the same.
7. Rounded grain of quartz with attached crystal of iron pyrites.

Discussion.

The President expressed his sense of the value of Mr. Phillips's communication.

Dr. Sorby expressed his agreement with the paper, to which he had listened with great interest, especially as the author had approached the subject from a point of view somewhat different from his own. He was especially glad to find that his opinions were confirmed by the author, especially as to the crystals of quartz in certain sandstones. The observations as to the time required to wear down a grain of sand were especially valuable. He had found the drift sands of the Yorkshire coast almost all angular; but then those examined by Mr. Phillips were from another locality, which might explain the difference in their observations. He should only regard sand as æolian when a very large proportion of grains were rounded.

* "Further Notes of Triassic Borings near Warrington," read before the Manchester Geol. Soc. June 29th, 1880.

So far as his observation had gone, the sands of the dunes on our coasts were not much more rounded than other sands.

Dr. Hicks said that the condition of the Barmouth Grit led him to think that the materials had not drifted from far. He had also observed that there was a large proportion of rounded grains in the Stiper Stones; were we to suppose these to be blown sands? Rounded grains were still more common in the quartzites of the N.W. of Scotland; we must believe therefore that there was, still remaining at the time they were deposited, an adjoining great land-area or the materials from one not far away.

Mr. De Rance said that the Keuper beds under the Marls were now divided into the Water-stones, soft current-bedded sandstones called Frodsham beds (which denoted entirely different physical conditions and contained the millet-seed grains), and then the Lower Keuper building-stone (*Labyrinthodon*-beds). Then came a line of erosion. In the Bunter series were the Upper Mottled Sandstones (with the millet-seed grains), then the Pebble Beds (which had a different kind of current-bedding from that of the Frodsham beds), then another line of erosion and the Lower Mottled Sandstone with millet-seed grains again. The bedding of the sandhills of Lancashire much resembled that of the Frodsham and other millet-seed beds in their high angle and rapid change.

Mr. Rutley said he had examined eruptive rocks rather than sedimentary, but could not but express his gratification at the agreement between two such observers as Dr. Sorby and Mr. Phillips. He called attention to the presence of felspar in many of the sandstones described, and suggested that it was possible for such sandstones to be changed into felstone. There was often much difficulty in distinguishing between the finer-grained igneous and sedimentary rocks. He also called attention to the development of microcrystalline structure in felspar crystals.

Mr. Blanford said that some years ago he had examined the Indian desert, and found the grains of sand well rounded. They were mostly of quartz, with a few of felspar and occasionally of hornblende. The strongest wind there blows from the west; the sands had come from the coast and the river Indus; and the sand in the bed of the river was also rounded. The blown sand appeared unstratified.

Mr. Phillips said that the grains of millet-seed sandstone were much more rounded than was usual in sea-sand. He thought the rounding of felspar was often due to disintegration by decomposition. With regard to Mr. Blanford's remarks, he could only say that he believed the grains of all the desert-sands which had been yet examined had been found to be much rounded.

3. Interglacial Deposits *of* West Cumberland *and* North Lancashire. By J. D. Kendall, Esq., C.E., F.G.S. (Read November 17, 1880.)

[Plate III.]

Contents.

1. Introduction.

The glacial deposits of these districts are capable of a threefold division, as below :—

1. Boulder-clay (Upper).
2. Sand, Gravel, and Clay.
3. Boulder-clay (Lower).

Seldom do we find the whole three members present in one section. Sometimes the Lower Boulder-clay alone is found; at others this is overlain by sand or gravel or clay, or by some or all of these rocks. In other cases we find the series complete. They occur almost continuously, in more or less completeness, from the sea-shore to an altitude of 500 feet; and from that level they appear in patches up to 1000 feet above the sea.

The two Boulder-clays have the ordinary character, and are very much alike, except that the lower is tougher than the upper and contains larger boulders. The character of the included stones is the same in both clays, as well as in the middle sands and gravel. Some most remarkable facts are presented by the distribution of these boulders*.

Associated with these glacial beds, and occurring at various places, sometimes inland, sometimes along the sea-coast, between high- and low-water marks, there are a number of deposits of vegetable matter, which hitherto have been almost entirely neglected by geologists.

When occurring on the sea-shore, these deposits usually pass by the name of "submerged forests." I am, however, inclined to doubt the accuracy of this appellation. After a long and careful investigation into the nature of these deposits, I have come to the conclusion that they are not forests at all, nor the sites of forests, as will appear further on.

* "On the Distribution of Boulders in West Cumberland, by J. D. Kendall, C.E., F.G.S.," vol. v. Trans. Cumberland Assoc. for the Advancement of Lit. and Science.

2. Observed Facts.

Lindal deposit.—The first of these deposits to which I shall refer has already been dealt with by two other writers:—

First, in vol. xviii. p. 274 of the Quarterly Journal, in a short paper by the late Mr. John Bolton, "On a Deposit with Insects, Leaves, &c."; *secondly*, in vol. xix. p. 19 of the same Journal, in a paper by the late Miss Hodgson.

A comparison of these papers will show that the writers differed seriously about the facts with which they dealt. It is therefore not surprising that they arrived at very different conclusions.

Owing to this discrepancy, I have been at some pains to ascertain the facts accurately; and I give them below.

The position of the deposit referred to by the above writers is shown on the map (Plate III. fig. 1). It occurs near Lindal in Furness. In figs. 2–4 a plan and two sections of the deposit are given. The data from which these sections were prepared are given below; they were obtained by a number of shafts and boreholes put down by the Ulverston Mining Company in search of hæmatite. The positions of the boreholes are shown in the plan and sections.

Sections of Boreholes.

(Explanation of local terms used:—Pinel = Boulder-clay; Black muck* = Vegetable deposit.)

Borehole No. 41.

	Thickness of each stratum. ft.	in.	Depth from surface. ft.	in.
Surface-soil	2	0	2	0
Grey pinel	66	0	68	0
Limestone	29	0	97	0

Borehole No. 42.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Blue clay	3	0	4	0
Gravel and stones	20	0	24	0

Borehole No. 43.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Gravel	1	0	2	0
Blue clay	1	6	3	6
Pinel (blue)	4	0	7	6
Gravel	9	0	16	6
Gravelly pinel	10	0	26	6
Black muck (woody)	5	0	31	6
Blue sand	4	0	35	6
Grey pinel	5	0	40	6
Limestone	2	0	42	6
Grey pinel	10	0	52	6
Jointy limestone	28	0	80	6

* The use of the term "Black muck" is here clearly wrong, but quite a pardonable mistake for a borer to make. "Black muck," as that term is usually understood in Furness, does not contain any vegetable matter.

Borehole No. 44.

	Thickness of each stratum. ft.	in.	Depth from surface. ft.	in.
Surface-soil	1	0	1	0
Bluish clay	3	0	4	0
Gravel	18	0	22	0
Blue stone	1	6	23	6
Red pinel	6	0	29	6
Grey pinel	9	0	38	6
Black muck (woody)	7	0	45	6
Blue sand	3	0	48	6
Yellow clay	3	0	51	6
Grey pinel	3	0	54	6
Reddish pinel with limestone	8	0	62	6
Red clay	4	0	66	6
Limestone	22	0	88	6
Yellow clay	3	0	91	6

Borehole No. 45.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Gravel	22	0	23	0
Grey pinel	14	0	37	0
Black muck (woody)	20	0	57	0
Blue sand	7	0	64	0
Grey pinel	7	0	71	0
Dark clay	10	0	81	0
Limestone	20	0	101	0

Borehole No. 51.

	ft.	in.	ft.	in.
Surface-soil	2	0	2	0
Red pinel	13	0	15	0
Grey pinel	43	0	58	0
Black muck	5	0	63	0
Blue clay	2	0	65	0
Yellow gossan	1	0	66	0
Red pinel	9	0	75	0
Iron-ore	0	8	75	8
Dark pinel	2	0	77	8
Limestone	10	6	88	2

Borehole No. 52.

	ft.	in.	ft.	in.
Surface-soil	2	0	2	0
Red pinel	30	0	32	0
Grey pinel	36	0	68	0
Red pinel	9	0	77	0
Limestone	10	0	87	0

Borehole No. 58.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Grey pinel	81	0	82	0
Blue pinel	4	0	86	0
Black muck (woody)	24	0	110	0
Blue sand	2	0	112	0
Red pinel	3	0	115	0
Red pinel and limestone	5	0	120	0
Iron ore and stones	2	0	122	0
Limestone	0	10	122	10

Borehole No. 59.

	Thickness of each stratum. ft.	in.	Depth from surface. ft.	in.
Surface-soil	2	0	2	0
Grey pinel	70	0	72	0
Black muck (woody)	1	0	73	0
Blue sand	2	0	75	0
Black muck (woody)	11	0	86	0
Blue sand	4	0	90	0
Red pinel	4	0	94	0
Limestone	9	0	103	0

Borehole No. 60.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Red pinel	30	0	31	0
Grey pinel	43	0	74	0
Black muck (woody)	12	0	86	0
Blue sand	2	0	88	0
Yellowish clay	2	0	90	0
Broken ground (dragged by workings)	22	0	112	0
Limestone	4	0	116	0

Borehole No. 61.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Grey pinel	69	0	70	0
Yellow pinel	2	0	72	0
Grey pinel	6	0	78	0
Black muck	9	3	87	3
Blue clay (sandy)	3	0	90	3
Limestone	0	8	90	11
Red pinel	3	0	93	11
Limestone	1	0	94	11

Borehole No. 62.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Grey pinel	88	0	89	0
Black muck (woody)	11	0	100	0
Blue clay	2	0	102	0
Yellow sand	6	0	108	0
Red pinel (with ore)	4	0	112	0
Soft stone (with ore)	3	0	115	0
Limestone with clay joints	21	0	136	0

Borehole No. 63.

	ft.	in.	ft.	in.
Surface-soil	1	0	1	0
Grey pinel	87	0	88	0
Black muck (woody)	10	0	98	0
Blue clay	3	0	101	0
Red pinel (with ore)	4	0	105	0
Red pinel (with stone)	8	0	113	0
Limestone	8	0	121	0

Borehole No. 64.

	Thickness of each stratum. ft.	in.	Depth from surface. ft.	in.
Surface-soil	1	0	1	0
Grey pinel	92	0	93	0
Black muck (woody)	20	0	113	0
Blue clay	2	0	115	0
Red pinel	9	0	124	0
Iron-ore	0	11	124	11
Rottenstone	0	8	125	7
Iron-ore	1	3	126	10
Rottenstone	0	8	127	6
Iron-ore	2	6	130	0
Grey limestone	20	0	150	0

Borehole No. 65.

Surface-soil	1	0	1	0
Grey pinel	99	0	100	0
Black muck (woody)	20	0	120	0
Blue clay	2	0	122	0
Yellow sand	3	0	125	0
Limestone	3	0	128	0

Borehole No. 66.

Surface-soil	1	0	1	0
Grey pinel	96	0	97	0
Yellow sand	1	0	98	0
Black muck	18	0	116	0
Blue sand	2	0	118	0
Yellow gossan	6	0	124	0
Limestone	1	6	125	6

The pinel or Boulder-clay overlying the Black muck or vegetable matter in the above sections is the Upper Boulder-clay, having a greyish and ochrey matrix, and containing numerous boulders, some as much as 2′ 0″ × 1′ 3″ × 1′ 3″; but the majority are below 3″ in diameter. Coniston grits and flags, from the adjacent highlands, are the principal rocks represented. Besides these, however, there are St.-Bees Sandstone, Eskdale granite, Carboniferous Limestone, &c.

The extent of the deposit has not yet been proved in either a N.E. or S.W. direction, as shown on the section AB (fig. 3). So far as is at present known, it covers an area of about 34 acres.

For a list of the plants &c. found in this deposit, the two papers above referred to should be consulted, as I had only an opportunity of seeing some of the vegetable deposit as it came out of the boreholes. It was then too much broken up to enable me to identify any of the plants.

Crossgates Deposits.—Several deposits similar to that at Lindal have been met with at Crossgates, in working the hæmatite-mines. In some cases they were covered up by 9 or 10 fathoms of Boulder-clay; and they invariably rested on clay. I have seen a large quantity of the woody matter which came from some of these deposits; but no correct information has been preserved as to their extent and thickness. Accumulations of similar material have been met with in the solid rock, as shown in the following section:—

Section obtained by Boring at Crossgates.

	Thickness of each stratum.		Depth from surface.	
	ft.	in.	ft.	in.
Soil	2	0	2	0
Gravel and clay	24	0	26	0
Decomposed limestone	17	0	43	0
Yellow clay mixed with iron-ore	4	0	47	0
Black muck	4	0	51	0
Iron-ore (dark-coloured)	2	0	53	0
Black muck mixed with iron-ore	6	0	59	0
Iron-ore	8	0	67	0
Decomposed limestone	7	0	74	0
Black woody deposit	12	0	86	0
Decomposed limestone	6	0	92	0
Black mould and wood	2	0	94	0
Yellow clay mixed with iron-ore	16	0	110	0
Black mould mixed with iron-ore	10	0	120	0
Black mould	4	0	124	0
Black mould mixed with iron-ore and limestone	3	0	127	0

Walney Deposit.—On the western shore of the island of Walney, and about a mile south of the village of Biggar (fig. 1), there is a vegetable deposit, in many respects like that at Lindal; but not much of it is exposed. A plan and two sections of it are given in figs. 5–7.

The deposit *rests* on Boulder-clay certainly; but I have not been able to prove that it is *overlain* by the same formation. Still I think there is very little doubt about it when we look at the sections, and when we know that the shore is travelling rapidly landwards. On the occasion of my visit I had not time to make any observations on the inner nature of the deposit with the view of determining the different kinds of plants enclosed in it; but I may state that, externally, it is very much like other deposits that I shall describe more in detail further on.

Drigg Deposit.—On the shore opposite Drigg (Plate III. fig. 1), there is another woody deposit. A plan and several sections of it are given in figs. 8–11. In one part of it I sunk a shaft, as shown on the plan. A section of this shaft is given below.

A. Vegetable matter (brown) and grey sand in alternating layers of various thicknesses, the vegetable matter predominating. I found in it the elytra of beetles, acorns, oak-leaves, hazel-wood, alder-wood and leaves, stems of common bracken, pieces of *Sphagnum*, seeds of various kinds and sizes, and rush-like stems and leaves, the stems standing on end and crumpled endwise, as if by downward pressure, the leaves lying on their side. The following diatoms were found in this bed:—*Cyclotella minutula, Pinnularia viridis, Pinnularia oblonga, Gomphonema acuminatum, Himantidium bidens, Himantidium pectinale.*

B. Yellow and brown sandy clay in irregular layers.

C. Blue sandy clay.

D. Red and blue sandy clay, the last 12 inches redder and more clayey.

Some of the pieces of wood in A. were as much as 12 inches in diameter, but all lying on their side and partly flattened as if by pressure.

Here, as at Walney, we find Boulder-clay under the deposit, but we have no direct proof of its having been overlain by that formation.

St.-Bees Deposit.—A few miles further north than Drigg, along the coast, opposite St. Bees (Plate III. fig. 1), there is another deposit, which I have examined more minutely than any of the others. A plan and two sections of it are given in figs. 12–14. In this deposit I have sunk several shafts and boreholes, sections of two of which (Nos. 1 & 8) I give below.

Shaft No. 1.

A. Vegetable matter (brown) and grey sand in layers of different thicknesses. The vegetable matter contains seeds of various sizes, leaves and stems of rush-like plants, hazel-nuts, leaves and wood of the oak, alder, and hazel. The rush-like stems are numerous, and vary in length from 1 to 3 inches; they are standing erect, and crumpled endwise, like those found at Drigg. The following diatoms have been found in this layer:—*Epithemia turgida*, *Epithemia granulata*, *Epithemia proboscidia*, *Pinnularia acuta*. A vertebral column about the size of that of a rat was also found in this bed.

B. Grey sandy clay containing a few rush-like leaves and the elytra of beetles.

C. Hazel-wood, nuts, and leaves, also leaves of the oak, beech, and alder.

D. Similar to A, but containing more leaves and hazel-nuts.

(Boulder-clay.)

Shaft No. 8.

A. Vegetable matter (brown), containing wood and leaves of the same kinds as those found in the same bed in Shaft No. 1.

B. Fine blue clay with rush-like stems standing upright, and the elytra of beetles.

C. Vegetable matter consisting almost entirely of leaves of the oak, alder, and willow, and hazel and alder wood.

D. Brown sand and vegetable matter with some rush-like stems standing upright and crumpled.

On the surface of the deposit there are a considerable number of stems of oak and alder, the former turned black and the latter pink; some of them are as much as 12 and 18 inches in diameter. I also found a large piece of the stem of a coniferous plant about 18 inches in diameter. Under the microscope it was like the yew. These stems and branches all lie on their sides. In several parts of the deposit there are root-stocks of oak and alder with about 12 inches of stem standing, as though they had grown where we see them: the rootlets, however, are imbedded only in vegetable matter; they do not extend into the underlying earth.

Near the upper edge of the shingle, on the beach, two boreholes were put down for the purpose of proving whether or not the vegetable deposit extended so far inland. One of these boreholes is shown in the section A B, fig. 13. The particulars of it were as follows:—

Borehole No. 2.

	Thickness of each stratum. ft. in.	Depth from surface. ft. in.
1. Shingle	1 6	1 6
2. Sand and gravel	1 6	3 0
3. *Vegetable matter*	8 6	11 6
4. Boulder-clay (grey)	0 6	12 0

The vegetable matter (No. 3) in this section was very soft and spongy, easily pierced by the boring-tool, and quite unlike that found in any of the pits or bores made on the shore, which was particularly difficult to bore through; in fact No. 3 is more like the soft peaty deposit which occupies the flat ground in St.-Bees valley. Two years ago a great length of drains was cut in this peaty matter; and I had then a good opportunity of ascertaining the nature of it. It, however, was nothing like the vegetable matter which occurs on the shore, being much more spongy, and containing a far larger quantity of water, and altogether having more the appearance of peat, which in fact it is. The vegetable matter on the beach contains very little, or almost no water, notwithstanding that it is covered twice every day by the tide. Another difference between the two deposits is that the one on the shore is quite laminated, whilst that in the valley is totally devoid of lamination. About eighteen months ago Pow Beck, during a freshet, diverted its course just where it passes on to the shingle of the beach (see Section A B, fig. 13). In the new course a large patch of peaty matter, similar to that in the valley, was exposed. After seeing that, I had no doubt whatever that the vegetable matter found in borehole No. 2 was the same, and not at all like that found on the shore.

Maryport Deposit.—About halfway between Allonby and Maryport, and about one third of the range of the tide from low-water mark (Pl. III. fig. 1), there is another vegetable deposit; but it is not very well exposed.

I have not dug through this deposit, and therefore cannot say what is below it; and the soft silt, which covers the shore in the neighbourhood, prevents any information on that head being obtained. It has the same external appearance as all the other deposits, besides being laminated and very much more compact than peat. It contains a large number of seeds about the size of gun-shot, and a quantity of rush-like leaves, as well as pieces of hazel and alder wood. The wood is in every case flattened as if by pressure.

There is another and similar deposit about a quarter of a mile further on the shore towards Allonby; but only the upper surface of it can be seen. Near Beckfoot, I am told, there is another; but that I have not yet visited; nor have I seen one which occurs at Cardunock, on the Solway.

All the deposits described, whether on the sea-shore or inland, have the same compact nature, and, so far as I have been able to ascertain, contain the same kind of plants.

3. Deductions.

So little was known of the extent of the Lindal deposit at the time Mr. Bolton and Miss Hodgson wrote, that its real geological importance was missed. We now see that it is overlain by an immense mass of Boulder-clay, in some places nearly 100 feet thick; it is also underlain by Boulder-clay; so that I think we may fairly say it is interglacial. The impossibility of its being a recent introduction, carried down by means of swallow-holes, as suggested by Miss Hodgson, must be apparent to every one now that we know more of its extent and real nature.

We may ascribe a like (that is, interglacial) age to the deposits at Crossgates. The deposits in solid rock were, I believe, thrown down in preexisting cavities in the Limestone at the same time as the deposits immediately below the Boulder-clay.

The shore-deposits, so-called submerged forests, I think are also of the same age. We are not able to prove it so directly as in the case of the other deposits; but I think that a careful consideration of all the facts must lead any one to the conclusion that they are interglacial. The fact upon which I most rely is their compact nature, which, to me, speaks most forcibly of their having been subjected to great pressure, such as would be the case if they had been overlain by the upper glacial beds. They are altogether unlike the spongy peat which occurs in St.-Bees valley, and quite as unlike any of the vegetable deposits which usually go by the name of peat, although many of the species of plants found in the shore-deposits are common to peaty accumulations.

These shore-deposits all rest on the *Lower* Boulder-clay, a fact which is somewhat remarkable if they are of postglacial age. Why should we not find some of them on the Upper Boulder-clay? Besides, how can it be for a moment doubted that the Walney deposit extends below the Boulder-clay, although this has not been directly proved. Referring to Plate III. figs. 6 & 7, we see that the deposit dips towards the land, and that it is only about 50 feet from high-water mark, where we have the Upper Boulder-clay. When to these facts we add that the shore is travelling rapidly inland, it seems to me we are bound to admit the Interglacial age of the deposit.

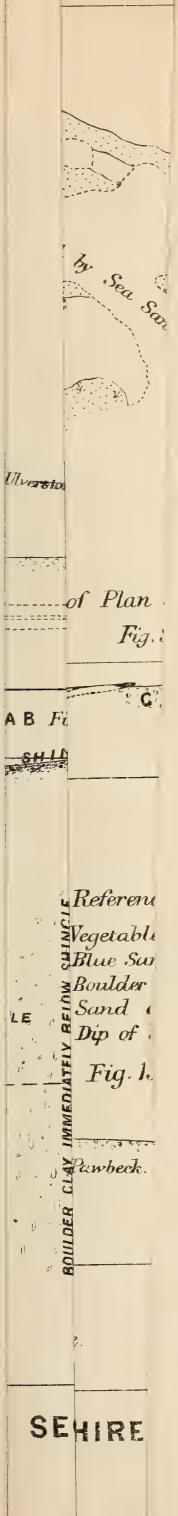
Usually these deposits on the sea-shore pass by the name of "submerged forests;" but the conclusion to which I am led is, as already stated, that they are not forests at all, nor the sites of forests, but that the vegetable matter has been accumulated under water. All the facts but one point in this direction: the Diatoms, the rush-like stems and leaves (probably of a species of *Sparganium*), and the interbedded layers of sand, all speak of watery conditions; the only fact which seems to me to indicate in any way that these deposits are the remains of ancient forests that grew on the spot, is the occurrence in them of a few root-stocks in their normal position.

But, as I have already pointed out, the rootlets from these stocks do not pass down into the underlying Boulder-clay, but are simply imbedded in the neighbouring woody matter. Some of these root-stocks belong to trees which must have been at least 18 inches in diameter; so that if such trees could have derived their necessary nourishment from a woody soil of this kind, it is perfectly certain they would not have been able to stand in it, because there would be nothing of any weight or tenacity for the roots to lay hold of. The presence of such root-stocks, it seems to me, may be better explained by supposing them to have been floated to the positions in which we see them. The position in which they now stand is that of flotation; that is to say, a root-stock would be floated and dropped in water with the same side up as when it was growing.

The inner nature of the shore-deposits being precisely the same as that of the cavernous deposits found at Crossgates is also suggestive of drifting; for clearly the latter are not on the site of an ancient forest, but have been carried to their present resting-place by water.

The facts presented by these deposits seem to me to have a most important bearing on the question of the formation of coal. We have here similar underclays to those which accompany coal-seams, and the same kind of intercalated clay-bands, both of which, in the case of coal, suggest watery conditions just as much as they do in the deposits under consideration. I think it is just as impossible that trees can have grown in the underclays of coal, which at the time would be soft and incoherent, as that they can have stood in the woody matter of the so-called "submerged forests." The *Stigmaria* rootlets of the coal may be accounted for in the same manner as the root-stocks which are found in vegetable deposits like that at St. Bees. The trees which have been found rising out of coal-seams and passing into the overlying strata, may be explained by supposing them to have been so loaded at the root when they were deposited that their position of flotation was erect. In this way the whole Coal-measures may have been deposited during a gradual subsidence without any of the periods of cessation demanded by those who hold that coal-seams are the remains of forests which grew *in situ*.

On the assumption that the shore-deposits are "submerged forests" of recent age, it has been often held that they indicate a subsidence of the coast; and writers, in consequence, have had to make the land rise and fall in a very remarkable and erratic manner, when dealing with the phenomena of "raised beaches" on the one hand and "submerged forests" on the other. The view just enunciated simplifies matters very considerably, as, according to that, the vegetable deposits on the shore do not necessarily indicate either a rise or a fall of the land in recent times.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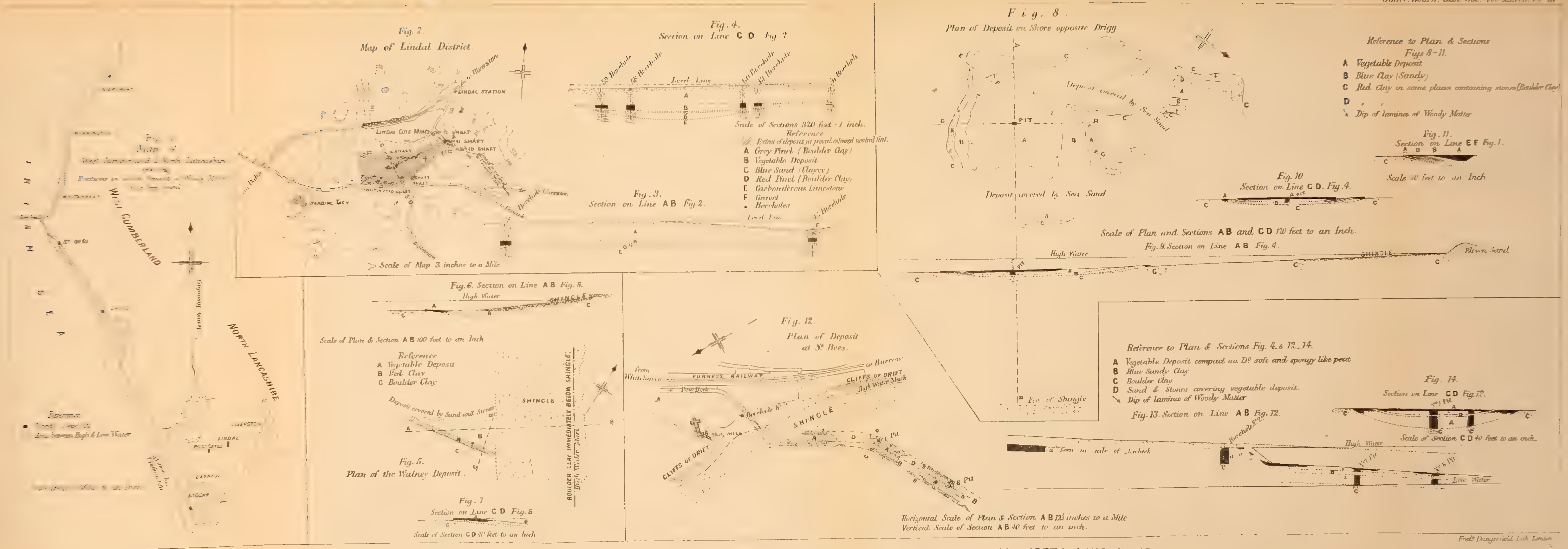


MAPS, PLANS AND SECTIONS OF INTERGLACIAL DEPOSITS OF WEST CUMBERLAND AND NORTH LANCASHIRE.

EXPLANATION OF PLATE III.

Plans and Sections illustrating the Interglacial Deposits of West Cumberland and North Lancashire.

Fig. 1. Map of the district, showing the positions in which deposits of woody matter have been found.
Figs. 2–4. Map and sections in the Lindal District.
5–7. Plan and sections of the Walney Deposit.
8–11. Plan and sections of Deposit on shore opposite Brigg.
12–14. Plan and sections of Deposit at St. Bees.

Discussion.

Mr. C. Reid said that in the Cromer Forest bed he had dug up many stumps of trees asserted to have been *in situ*, and had found them not to be so. He thought that great caution was needed in asserting trees to be *in situ*. They would usually sink in a vertical position with their roots downwards. Sometimes portions of the soil in which the trees had grown were retained among the roots, and differed entirely from the matrix.

Rev. H. H. Winwood pointed out that trees often grew in a soil, but the roots did not pierce the underlying clay. Might not this be the case with the Cromer trees mentioned by Mr. Reid?

Rev. J. F. Blake spoke of a boring at York with peaty matter in the midst of the Boulder-clays.

Mr. Tiddeman asked whether it was quite certain that there was Boulder-clay above and below these peaty deposits.

The Secretary replied that the author stated so distinctly in the paper.

The President spoke of the importance of comparing together the results of investigations in different areas.

4. *On the* Serpentine *and* associated Rocks *of* Anglesey; *with a* Note *on the so-called* Serpentine *of* Porthdinlleyn (Caernarvonshire). By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S. (Read November 3, 1880.)

1. Anglesey with Holyhead Island.

The serpentine from the vicinity of Rhoscolyn, though known within a limited area as an ornamental stone, does not appear to have received much attention from geologists. It is dismissed in Professor Ramsay's memoir on North Wales in a few brief sentences, and has not, so far as I know, met with fuller notice in any other quarter. On the Geological-Survey map it is delineated as forming an elongated lozenge-shaped patch about a mile and three quarters in length from E. to W., extending inland north of Rhoscolyn from the west shore of Holyhead Island, and occurring in several smaller patches on or near the opposite coast of Anglesey. In each of these localities I have studied the rock in the field, and have examined microscopically the specimens there collected. The results, I hope, may be of some use, though, after three separate visits, I have not been able to visit every one of the outcrops or examine minutely every part of the district. Owing to the intricacy of the coast in certain places, a map on a considerably larger scale than 1 inch to the mile would be required before an elaborate study could be undertaken.

The questions which I have attempted to solve (as in all former studies of serpentine), were (1) its relations to the other associated rocks, and (2) its nature and origin.

The ordinary rock in the vicinity of these masses of serpentine is a dull bluish or greenish schist, composed chiefly of minutely crystallized micaceous or chloritic minerals with some quartz, the foliation being parallel to the bedding. The latter is generally very distinct and sometimes exhibits very remarkable crumplings. The serpentine occurs in low rugged knolls, cropping out here and there from the fields over which in the map the colour denoting its presence is extended—the general aspect of the rock masses reminding us of the serpentines of Cornwall, Scotland, and Italy. It differs markedly in all its characters from the ordinary schists of the district, and, where associated with the latter, occurs in such a manner as to suggest either intrusion or sporadic metamorphism of a very singular character. This is also suggested by the mapping; but it is even more conspicuous in the field.

My examination, however, showed me that under one name two distinct rocks had in some cases been confounded, viz. a true serpentine and a gabbro, especially in the Anglesey group. For instance, if we alight at the Valley Station on the Bangor-Holyhead railway, and follow the road to Four-mile bridge, we observe in the fields on our left, near Ty Newydd, a long craggy mass of serpentinous aspect, the northern edge of the largest patch in Anglesey, according to the map. But on reaching this we find it a mass of gabbro, generally rather coarse—considerably altered, no doubt, but

Fig. 1.—*Junction of Schist and Serpentine.*

A. Schist. B. Serpentine. C. Sand.

unmistakable. There is, however, a small inconspicuous outcrop of true serpentine, separated from it by some grass, about seventy yards to the north of its eastern end. From the west end of this gabbro *massif* we made* for the shore. Here we found an irregular rocky coast-line fringed with skerries and islets, mostly dry at low tide. Some are schist, marvellously contorted, others gabbro, a few serpentine. Without a large-scale map, it would be impossible to make the details intelligible; but it may suffice to say that we worked carefully along the shore to the inlet by Tyddyn Gob, examining the different rocks. In one place the evidence, though not perhaps absolutely conclusive, seemed strongly in favour of the serpentine being intrusive in the schist; for if the junction were due to a fault, this would be a very strange one (fig. 1)†. Further on (beneath a wall) gabbro is seen intrusive in serpentine, which has assumed, as is not uncommon in such cases, a locally schistose aspect. A large mass of gabbro forms an island near here. On the bank of an inlet near Tyddyn Gob is a rather schistose rock, which in the lower part resembles a foliated gabbro, in the upper a schist. Further to the south the schists are wonderfully contorted, and there is a small mass of serpentine near Ty Ucha (reached by crossing a causeway over an inlet); this is greatly crushed and slickensided. Appearances suggest an intrusive junction; but both

* On my first visit to this place I was accompanied by Mr. F. T. S. Houghton, to whom I am much indebted for kind help on this and a subsequent occasion.

† In the face of a crag facing S.E. and rising from the shore about the top of the letter *e* in *mile* on the map.

schist and serpentine are so much affected by subsequent changes that it is difficult to be sure.

On the north-eastern edge of this *massif* of serpentine (Survey map), near Cruglas Farm, five shallow pits have been opened in a low ridge east of the road, two being close together by the road and outside the enclosure. In one the rock is a normal serpentine, as it is on the right-hand side of the other; but on the left we find a tougher variety (see below, p. 46). I failed, however, to find any line of demarcation between the two varieties. The next two pits are in normal serpentine, veined in places with calcite. The last is a kind of ophicalcite, hard and tough. On my first visit I found a loose block, near one of the western pits, of a dark green serpentine full of lustrous crystals, up to 0·3 inch diameter, of a mineral of nearly the same colour. I could not then discover any of this rock *in situ*, and on a second visit, after a most careful search, aided by some of my students, was equally unsuccessful, though in one or two places the presence of a few minute crystals in the normal serpentine indicated a slight approach to it*. On the western side of the road a pit has been opened in a large mass of gabbro, some of which has a rather serpentinous aspect.

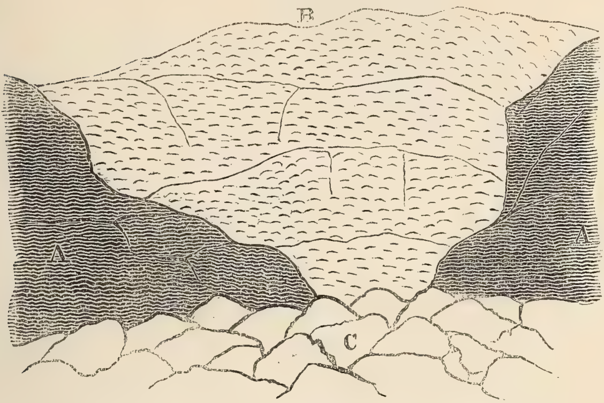
About a quarter of a mile further down the road we passed over a reddish serpentine, rather brecciated and veined with calcite. We again touched a little serpentine (dull green) near Gwrthya. All the south-western end, adjacent to the shore, of the large mass near Melin Carnau, coloured as serpentine on the map, is gabbro. Thence we worked along the shore northward till opposite Ynyslas. There is no serpentine here, the gabbro being succeeded by schists, some of which are, indeed, massive and serpentinous in aspect; but the difference is evident, even in the field, on careful examination. I failed to find any serpentine at the shore end of the slope opposite Ynyslas; the rock there is the green serpentinous-looking schist; nor did I see any in the isolated crags inland in the immediate neighbourhood. The railway crosses the mass which is represented on the map as running southward from Llyn Treflas; I walked along this, and found nothing in the cuttings but the green schist succeeded by the ordinary schists of the district.

A much larger mass of serpentine than any of the above is indicated on the map near Rhoscolyn, at the south end of Holyhead island. Specimens from this locality are familiar to me; but I have only examined the western portion of it in the field. As on the other side of the water, both schist and serpentine crop out here and there in rough knolls and ridges among the fields. The two most interesting exposures are on the western side of the western of two roads leading to Rhoscolyn. The first, near Ceryg Moelion, is a quarry approached by a driftway. Along this we pass a large mass of gabbro, which is succeeded by an outcrop of dark green serpentine; and beyond this we come to the quarry. It has been opened in a mass

* See below, p. 45, for a microscopic description.

of ophicalcite which is bordered by true serpentine on either side. The annexed diagram (fig. 2) roughly represents the relations of the

Fig. 2.—*Quarry at Ceryg Moelion.*



A. Serpentine, crushed and slickensided.
B. Ophicalcite. C. Débris.

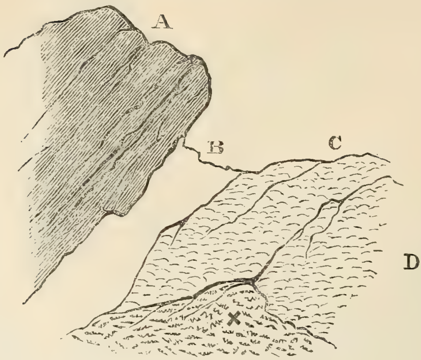
two rocks. The boundary between them is generally quite sharp; and the serpentine is shattered, greatly slickensided, and in parts almost flaky, as if it had undergone great pressure. The ophicalcite varies much: in parts nearer the edge it is evidently a breccia of angular fragments of dark serpentine united by crystallized calcite; in other parts the latter predominates and is mottled by a green serpentinous mineral without distinct evidence of fragments. The section is perplexing; but, after careful examination aided by the microscope, I think that we have here a fissure which has been connected with some faulting and has subsequently been filled up. As the serpentine itself contains little or no lime, and as the schists of the island are not markedly calcareous, one is disposed to attribute the calcite to infiltration from overlying masses of Carboniferous Limestone which have been subsequently removed by denudation.

Following the road for perhaps a quarter of a mile further south, we pass some more serpentine and several craggy outcrops of schist, and then in a field on the left find another interesting pit * which has been opened in order to work a band of steatitic rock. The annexed diagram (fig. 3) expresses the relations of these rocks.

A is a green schist with a rather high N.N.W. dip. B is the band quarried. It is about 4 feet thick, but is rather irregular, seemingly conformable with A, and distinctly schistose in structure.

* I believe it is called Plas Goch; but it is most difficult to obtain information as to names in these wild parts of Wales; the spot must be very near the division between the two quarter sheets of the Ordnance map,

Fig. 3.—*Quarry at Plas Goch.*



A. Green schist, well marked dip.
B. " Steatite " schist, partially quarried out.
C. Green schist, most massive and serpentinous-looking at ×.

It is very soft, like talc, and greasy to the touch, of a pale dull green or leaden colour. C is a less pure steatitic schist, which at D assumes a more normal character, and it dips to N.N.W. or N. × is more like a serpentine, and has more the aspect of an intrusive rock; it is of a dull-green colour, and has a slightly schisty structure, is harder than B, but can just be scratched with the nail. It contains numerous crystals of magnetite, commonly minute, but in places very distinct octahedra, which are sometimes nearly $\frac{1}{4}$ inch in diameter. The matrix, however, on close examination, rather resembles a massive chloritic rock, like some of the lapis ollaris of the Italian Alps (*e. g.* that from near Chiesa in the Val Malenco) than a true serpentine. To the latter, under the microscope, it has little resemblance. It consists of a thickly felted mass of a scaly or fibrous clear mineral, slightly tinged with green, and feebly dichroic. The brightest tint shown with crossed Nicols is a dull greyish white; and the mineral is either hexagonal or orthorhombic; minute granules, some fairly clear, some brown to opaque, are scattered about the slide (the larger crystals have been apparently torn out in preparing it), part of which are probably chromite. After two visits to the pit, and the best study that I can give to the rock, I am disposed to think that it is more probably a massive chloritic schist than a true serpentine, and that the appearance of intrusion is illusory. The quarried rock (B) under the microscope exhibits a thickly felted mass of almost colourless folia, which, in transverse section, do not show conspicuous foliation, together with some few scattered granules of opacite. With crossing Nicols they afford fairly bright pink and green colours, and are almost certainly talc, so that the rock may be regarded as a talc-schist.*

The following are the results of the microscopic examination of some of the above-mentioned rocks. The porphyritic rock found near

* I am since indebted to F. T. S. Houghton, Esq., F.G.S., for the following

the quarry south of Cruglas consists of three minerals:—(*a*) a clear transparent mineral, with a satiny texture and occasional very faint indications of two cleavage-planes; with crossed Nicols it presents a dark base crowded with irregular patches of minute fibrous microliths of a dull yellowish colour. (*b*) About an equal quantity of roundish or irregularly polygonal grains of a pale yellowish green mineral, which exhibits one marked set of cleavage-planes, and a second less perfect at right angles; these, especially the former, are further indicated by numerous grains and rods of opacite, probably magnetite. With crossed Nicols this second constituent is either black or shows a pale fibrous dull bluish mineral. The greatest absorption takes place when the cleavage-planes are parallel to one of the vibration-planes of the Nicols. (*c*) Scattered black grains and crystals of magnetite or possibly chromite. No structure resembling olivine occurs in the slide; so far as it is possible to conjecture the nature of the unaltered rock, it most resembles one that has consisted almost wholly either of two kinds of enstatite*, one richer than the other in iron, or of enstatite and hypersthene. I much regret that I could not succeed in finding the rock *in situ*.

The Ty-Ucha rock, on the contrary, has the granular structure (defined by wavy irregular strings) which is often seen in an altered olivine rock. These, with crossed Nicols, exhibit a slightly fibrous structure and bluish-white colour, with an occasional golden-yellow tint, as is common in serpentines, the interstices being dark or relieved by patches of dull bluish fibres. Opacite and larger grains, generally rounded, but sometimes clearly crystals of the isometric system, are scattered about the slide; probably these are magnetite. No appreciable quantity of any other mineral is present in the slide. This serpentine then probably results from the alteration of an olivine-rock, a kind of dunite.

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analyses:—I. is the dull-green chloritic rock, and II. the talcose schist. No. I., however, has not made it easier to identify the chief mineral.

I.		II.	
Water	11·09	Water	2·86
$Si\,O_2$	28·56	$Si\,O_2$	56·34
Al_2O_3	39·54	Al_2O_3	8·21
Fe_2O_3	0·99	Fe_2O_3	3·04
Fe O	2·87	Fe O	2·00
Cr_2O_3	traces.	Mn O	traces.
Mn O	traces.	Ca O	0·52
Ca O	1·73	Mg O	25·43
Mg O	15·79	Na_2O	0·79
Alkalies	0·70		
	101·27		99·19

* Prof. Maskelyne has described an enstatite rock (without olivine or other mineral, except perhaps diopside) from S. Africa. Another slide cut from an outcrop in this neighbourhood presents some resemblance to the above, though the constituents are more minute and more highly altered, and there is less iron.

The Ty-Newydd rock* is similar to the last, but contains a little of a mineral which, optically and in all other respects, resembles a rather altered enstatite. One of the black grains shows a parallel cleavage, as if it were a pseudomorph of enstatite in magnetite, a thing not very uncommon in the case of augite. A few strings of chrysotile traverse the slide.

The serpentine from Ceryg Moelion consists partly of a fibrous-looking doubly refracting mineral akin to chrysotile, and partly of a clear, rather satiny mineral, dark or faintly granulated with bluish light, resembling one of those described in the block found at Cruglas (*a*), with thickly clotted opacite in irregular strings and some scattered grains. It may be an altered olivine rock.

The rock from a small quarry about a quarter of a mile north of Plas Goch appears to be mainly composed of flaky mica-like plates of a doubly refracting serpentinous mineral, with the usual granules, rods, and clotted strings, probably of magnetite, and a very little of the mineral described above (*b*) in the block found at Cruglas. Of all those examined, it most resembles an altered olivine rock.

A slide cut from the tougher serpentine in the quarry south of Cruglas shows a rather peculiar structure. The slide is traversed by irregular strings of clotted opacite, and is composed of two closely associated minerals—one the scaly serpentine described above, the other exceedingly minute scales of a doubly refracting mineral, dichroic, changing from pale yellowish to dull grey-brown, and with the two Nicols giving fairly brilliant colours. There is nothing inconsistent with this serpentine being the result of the alteration of an olivine rock; but, so far as my experience goes, its appearance is exceptional. As stated above, I could see no evidence that this variety was intrusive in the normal serpentine.

Microscopic examination confirms the view taken in the field, that several of the so-called serpentines are true gabbros. The specimen from the great mass near Ty Newydd shows the ordinary structure of a typical gabbro, though the felspathic constituent is wholly replaced by secondary products (much being an opaque dust), being thus a variety of the saussuritic mineral so common in old gabbros. There is also plenty of a rather coarsely cleaved diallage, with probably some ordinary augite, and a few grains of a more finely

* I am indebted for the following analysis of this serpentine to the kindness of F. T. S. Houghton, Esq., F.G.S.:—

Water	12·52
$Si\,O_2$	38·62
Al_2O_3	4·15
Fe_2O_3	5·21
$Fe\,O$	4·34
$Mn\,O$	traces.
$Ca\,O$	traces.
$Mg\,O$	33·83
Alkalies	0·70
	99·37

cleaved fibrous mineral of an altered aspect. This may be only the result of pseudomorphic action on the diallage; but it may have been from the first a separate mineral. I incline to the latter view, as the normal constituent is sometimes altered, but seems then to produce a different mineral.

A specimen from the islet near the south shore closely resembles the last. Here the pyroxenic mineral sometimes contains microliths, apparently of augite, sometimes exhibits lamellar twinning; it is occasionally altered as in the last case. A third specimen, from a knoll on the shore between an outcrop of schist and another of serpentine, corresponds generally with the above.

Specimens of the normal schist from near the chapel on the Holyhead island, from near Tycoch, and within about 5 feet of the serpentine at the presumed intrusive junction (see above, fig. 1, p. 41) have been examined. They are representatives of a class of schists of which I have seen and received numerous examples from Anglesey. Under the microscope they are seen to be composed mainly of two minerals, both of minute size:—one quartz; the other a greenish mineral in little scales*, fairly dichroic, changing from a greenish yellow to a strong green, occurring also in veins in little tufts: it resembles a chlorite more than a mica. There is an occasional granule of epidote and a good deal of a sort of grey earthy dust, sometimes in clots, probably in part decomposed magnetite or ilmenite. There are also some vein-like bands of clear quartz, probably segregation-products. The third specimen has a rather coarser structure, and contains some scattered quartz-grains which may indicate original constituents. These rocks show a banded structure, probably due to original bedding; but they are very highly altered. The schistose rock at Tyddyn Gob, as might be supposed from its aspect, is very different. It has a marked foliated structure, being chiefly composed of wavy bands of an earthy mineral, almost opaque, and of a nearly colourless fibrous mineral, probably a variety of actinolite. Among the latter, in the lower and coarser rock, are the remains of a mineral with well marked parallel cleavage, from which the other may have been produced by secondary change. In appearance the mineral more resembles augite, and it is practically not dichroic; but in other optical properties it agrees better with hornblende; a little epidote is present. I cannot help suspecting the possibility of this rock being an altered gabbro with pressure foliation; but if so, it is a most exceptional case.

From the above observations it will appear that the whole of this district needs remapping; and this task will not be an easy one. That the gabbro is an ordinary igneous rock cannot, I think, be doubted. As regards the serpentine, the evidence is a little less clear. The microscopic structure, owing probably to the great age of the rock, is rather obscure and anomalous; its relations to the schist are not clearly displayed. Still the structure in several cases coincides with that of serpentines which we need not hesitate to

* Not more than ·001 inch diameter.

consider altered olivine rocks, such as those of Cornwall, Scotland, Italy, &c.; the general aspect of the rock in the field perfectly agrees with the same; and its relation to the schist would be most difficult to explain, except on the theory that it was intrusive in the latter. We must also remember that olivine rock partially altered has been detected in the Lleyn peninsula*. The evidence in favour of the serpentine being produced from the schist by some kind of selective or local metamorphism is of the weakest possible description. We therefore need not hesitate to add the Anglesey serpentines to the list of altered peridotites.

2. The so-called Serpentine of Porthdinlleyn.

The northern and larger part of the promontory at Porthdinlleyn (west of Nevin) is coloured as serpentine in the Survey map, and thus noticed (by Mr. Selwyn) in the memoir†:—"The rock at Porthdinlleyn is a kind of coarse green and purple serpentine, with nests of red jasper; veins of the serpentine are observed to dash in among the slaty series at Porthween." So far as true serpentine is concerned, I might have modelled this note on the well-known chapter concerning the snakes in Iceland; for there is none at Porthdinlleyn. The rocks, however, which I examined in my search for serpentine are so interesting that I am tempted to add a few words concerning them.

Specimens of several of these rocks have been examined microscopically; and one or two exhibit structures of much interest. On the present occasion, however, I shall not enter into details foreign to the immediate subject, but only endeavour to identify the specimens. The first rock seen (by a landing-stage) as we approached Porthdinlleyn along the shore from Bwlchdinlleyn is a massive green rock of serpentinous aspect. In the craglets and reefs near the hamlet itself we find a similar rock which also shows in parts a distinctly brecciated structure, pale-green fragments of various sizes (generally up to 2 or 3 inches diameter, but in one case about 18 inches) occurring in a darker and more ashy-looking matrix. In other parts the structure more resembles brecciation *in situ*; sometimes the rock is almost spheroidal, and reminded me of certain instances which I have seen in old igneous rocks of a rather basic nature, where the outer shells of the spheroid had become decomposed, simulating a conglomerate with but little matrix. A reddish variety of the compact rock also occurs; and these rocks continue for some distance to the north of Porthdinlleyn, the "nests of red jasper" (hæmatite with quartz, calcite, &c.) being in places very conspicuous. In the field it is very difficult to pronounce upon the nature of the above compact rock. It is hard, with a subconchoidal to rather argillaceous fracture, traversed by well-marked divisional planes, but

* Geol. Mag. dec. ii. vol. vii. p. 208.
† The Geology of North Wales, p. 170.

with no certain indications of bedding. The rock exhibits spots of epidote, varies in colour from a dull sap-green to a greenish-purple colour, is traversed by thin veins of quartz and calcite, and might be taken either for a compact chloritic rock resulting from the alteration of a uniform fine sediment, or for a very compact diabase. Under the microscope both varieties are seen to be rather decomposed, the slides being rendered more or less opaque with fine powdery ferrite, which sometimes also occurs in granules. There are indications of numerous microliths, some doubtless being felspar, and probably a plagioclase; these, in places, show a tufted, sometimes an almost spherulitic arrangement. In this are scattered some larger augite crystals, much altered but still recognizable. The green variety has some faint indications of a fragmental structure, and might be a tuff in which the outlines of the fragments were nearly obliterated. The structure of the redder variety is more distinctly that of a true igneous rock; and as I could see no signs of a division in the field, we may venture to identify these as compact diabases *, very probably old flows of a basaltic lava †. The breccia exhibits under the microscope a base of filmy pale-coloured viridite, in which are scattered numerous granules of ferrite, crystals of epidote, with other minerals of secondary formation, altered augite, and felspar, and scattered fragments, apparently of more or less glassy lapilli. Of the nature of some of the last there can be no doubt. The rock, then, is a "diabase tuff," of which probably a good deal was once a very fine dust.

For some distance to the north of Porthdinlleyn the dubiously "conglomeratic" aspect of the rock as above described continues; and then we find, on arriving within a short distance of the life-boat house, sections that, even in the field, are perfectly conclusive. The best occurs in a little cliff (an old quarry-face) looking seaward. On the sides of this (the section is about a dozen yards wide) we find a dull-green ashy-looking matrix, full of angular and subangular fragments of all sizes up to 3 or 4 inches diameter of a compact paler-coloured rock; and in the middle a mass of rounded blocks (a foot or two in diameter) which seems almost solid passes irregularly, but with fairly marked boundaries, into breccia. There can, then, be no doubt that we have here a true volcanic agglomerate, including either a thickly fallen mass of bombs or a small lava *coulée*. This view is fully confirmed by microscopic examination,—the breccia exhibiting a ground-mass, as above described, full of scattered fragments obviously of volcanic origin, some a brown slaggy glass, like a kind of tachylite, others compact basaltic scoria. The examination of a spheroidal mass from the agglomerate shows it to be highly decomposed compact diabase.

* The name diabase is given, though little or no chlorite can be recognized, because I know of none other that exists.

† I may mention that I have in my collection a rock microscopically identical with the above, which I collected between Glyn Garth and Beaumaris. These old basalts are, I suspect, not uncommon among the Welsh Pre-Cambrians, and in the field are hard to recognize.

Proceeding a little further, we find, about fifty yards south of the boathouse, a compact green rock with indubitable spheroidal structure. This rock now continues along the northern and western face of the peninsula, becoming in places very distinctly spheroidal. The face of a crag (a joint-plane) near the sea at the N.E. angle exhibits one of the most conspicuous instances of the structure that I have ever seen. The rock, where not spheroidal, is compact and sharply jointed, in one or two cases a little platy in structure. Under the microscope it is seen to be an altered basalt, the structure being recognizable, though the felspar is replaced by earthy decomposition-products, and the grains and crystals of augite are much altered. I also noticed one or two small dykes, seemingly of late date. The eastern side of the peninsula had occupied so much of my time that I was unable to examine into the relations of the above group of rocks with the schist of the district (which is not to be seen on that side), and had to be content with satisfying myself that, though there are igneous rocks, there is no true serpentine at Porthdinlleyn.

Discussion.

Mr. Bauerman had examined the steatite-deposit of the locality, and had arrived at much the same conclusions as the author. There were true serpentine rocks, and doubtful or "serpentinous" ones. He considered an examination of the composition of these rocks desirable.

Dr. Hicks congratulated the author on speaking of the intrusive origin of the Anglesey serpentines with a certain degree of doubt. He was himself inclined to regard these rocks not as intrusive, but as altered representatives of certain ancient sediments. He repudiated the notion of "selective metamorphism" being generally applicable to these rocks. The rocks at Porth Dunbar he regarded as mainly indurated and altered ashes.

Prof. Hughes pointed out that when the Survey map was made the definition of "serpentine" was much wider than that which was now adopted. He was not convinced of the intrusive character of the serpentines in the section given by the author, but thought it might be one of the numerous cases in which during the crumpling of the gnarled series the harder masses were protruded through the schists, producing small local faults. He believed that calcareous beds in the gnarled series, and magnesian minerals in the dykes, generally associated with the serpentinous rock and ophicalcite, were sufficient to account for both.

Mr. Hudleston had examined the rocks of the district, and thought they differed so greatly from the Cornish serpentines as to make it somewhat doubtful whether they could have been formed by the alteration of olivine rocks of intrusive origin. He was inclined to think that the Anglesey serpentines, like those of the Shetlands described by Dr. Heddle, might in part be altered actinolitic rocks.

The Author doubted whether the so-called steatite is really the normal mineral. Dr. Hicks had entirely misapprehended him; for he had no doubt that the true serpentines of the district were altered olivine rocks, and not metamorphosed schists. He considered the use of the term "serpentine" by the Survey, if it were as stated by Prof. Hughes (which he doubted), was one which was quite unjustifiable; nor could he agree with Prof. Hughes's explanation of the section showing an apparent intrusion of the serpentine into the schist. He could not admit that either the Anglesey serpentines or any Scottish serpentines which he had himself examined could have been formed by the alteration of actinolitic rocks.

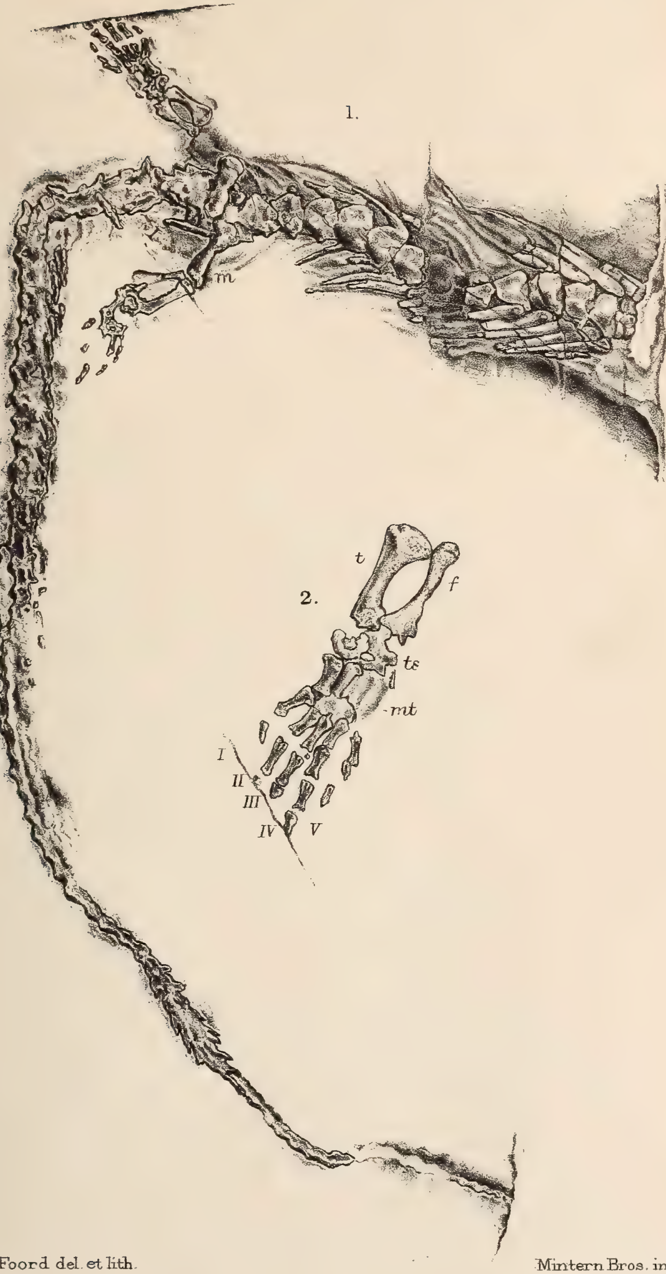
5. *On* Remains *of a* Small Lizard *from the* Neocomian Rocks *of* Comén, *near* Trieste, *preserved in the* Geological Museum *of the* University *of* Vienna. By Prof. Seeley, F.R.S., F.G.S., of King's College, London. (Read December 1, 1880.)

[Plate IV.]

Professor Eduard Suess, F.M.G.S., recently received from Comén, near Trieste, a specimen showing the hinder half of the skeleton of a lizard which he has desired me to describe. Unlike the two fine slabs from the island of Lesina, preserved in the k.-k. geologische Reichsanstalt, which are in a pale yellowish limestone matrix, this specimen is from a limestone slab nearly black; the animal shown upon it has lain exposed for some time in the quarry and suffered by the solvent action of the rain. Prof. Suess mentioned to me that the colour merely indicated one of the many alterations in the limestone, and that, since it was collected by a former pupil, no doubt could attach either to its stratigraphical or geographical position. Prof. Kornhuber does not appear to have been quite certain as to the position of the Lesina rocks in the Cretaceous series; but while I was in Vienna, Professor Pisani mentioned to me that he had identified thirteen species of fish with Upper Neocomian species; and as fish constitute the chief fossils of the deposit, this must be held conclusive evidence of the geological age of these lizards.

This new fossil (Pl. IV. fig. 1) at first sight presents a considerable resemblance to the *Hydrosaurus lesinensis* of Kornhuber, as was pointed out to me by Prof. Suess; but the differences are so remarkable and important that I find myself unable to include it in the same genus. The specimens in the Museum of the Imperial Geological Survey were shown to me by the Director Franz Ritter von Hauer. They are admirably preserved, and, as Kornhuber has stated, appear to indicate an animal with 9 cervical, 30 dorsal, and 2 sacral vertebræ, and a tail of which only the 24 anterior vertebræ are preserved. The type is distinguished by the remarkable stoutness of the dorsal ribs, by the very long and large neural spines and early caudal vertebræ; and it possessed well-developed limbs, of which the hinder pair were much larger than the anterior pair. The specimen which I have now to describe has only the hindermost 12 dorsal vertebræ preserved. There are presumably 2 sacral vertebræ; and then succeeds the tail, of which about 65 vertebræ are preserved or indicated by impressions; and it is probable that more remained in the slab which had been adjacent but was not collected.

The length of the 12 dorsal vertebræ is about 55 millims.; and the remainder of the vertebral column, as preserved, measures along the curves of the tail nearly 200 millims. The dorsal region is exposed so as to display the attachment of the ribs. The ilium is the



A.S. Foord del. et lith.

Mintern Bros. imp.

ADRIOSAURUS SUESSII.

only pelvic element clearly exhibited; and that is directed backward in the usual lacertian manner (fig. 1, I). The hind limbs are preserved, though they were fast becoming obliterated by weathering. The caudal vertebræ lie upon one side, and consequently do not give a very distinct idea of their forms. They, however, show no trace whatever of the neural spine, though the chevron bones are well developed, and are preserved down the greater part of the tail. The dorsal vertebræ apparently rest upon the neural surface and expose the visceral surface. This may be inferred from the form of the centrum, the curvature of the ribs, which are concave in length as exposed, and the fact that the ilium underlies the femur; but the face of each centrum has been somewhat dissolved, so that it cannot in any case be said to exhibit the unaltered appearance of the bones. Each centrum in the dorsal region is rather less than $\frac{1}{2}$ a centim. in length, and is about 6 millims. wide in front. The sides converge posteriorly to about 3 millims.; so that, besides being a far smaller animal, the lower dorsal vertebræ appear here to be relatively shorter, and the centrum, instead of having the concave lateral outlines of *Hydrosaurus*, has its side rather convex in length; and the anterior surfaces on each side of the anterior articulation look more forward and less outward than in that genus. There is, moreover, no indication of the transversely concave outline of the intervertebral union—but in place of it a notch in the anterior border, as though there were a small ossicle at the junction of each two vertebræ; but this apparent notch may be nothing but the neural canal exposed in this position by the thin base of the centrum being there dissolved. As the vertebræ pass downward towards the sacrum, their aspect seems to be less massive, and the posterior end becomes a little more compressed from side to side. There are slight indications of two ridges running longitudinally on the base of the centrum from the outer corners of the anterior cup towards the posterior articular ball. All the dorsal vertebræ were furnished with ribs; but they become shorter and smaller towards the sacrum. On the right side of the specimen they lie together, touching each other along their lengths, except in the case of the last three or four, which are only indicated by impressions. The ribs appear to be flat on the under side and moderately curved; the rib of the third vertebra preserved is 2 centims. long and 2 millims. wide at the proximal end. The ribs appear to be tubular and single-headed; they taper evenly to a blunt point, but scarcely give the impression of being relatively so stout as the ribs of *Hydrosaurus*. The sacral vertebræ are no better defined than those of the dorsal region, being partly covered by femoral bones. There is an angular bend in the tail, beyond which the vertebræ lie on their sides more perfectly displayed than in the case of the first few caudals. The neural arches of the caudal vertebræ were low, without any indication of neural spines, the neural arch being concave superiorly from front to back, and articulating with the arches of adjacent vertebræ by zygapophyses, which were elevated high above the neural surface. The neural arch widens in front, and is smooth at the sides.

There is no trace preserved of transverse processes, such as may be presumed to have existed. The chevron bones are relatively long and slender and directed backward parallel to each other. The vertebræ rapidly decrease in size, and in the latter half of the tail preserved are small. These hindermost vertebræ (that is, after about the thirty-fifth) appear to develop a slight neural spine, which is slender, directed backwards nearly horizontally, and terminates without any decrease in thickness, in a rounded end; but these spines can only be detected in some eight vertebræ. The neural arch appears to be preserved to the end of the series, where the whole lateral measurement of the vertebra is less than 2 millims., and its length does not greatly exceed 2 millims. The height from the base of the centrum to the middle of the neural arch at about the eighth caudal is $3\frac{1}{2}$ millims., the neural arch forming less than half of this height. The union between the centrums is not well defined. The chevron bones in the first dozen vertebræ appear to be about $5\frac{1}{2}$ millims. long. There thus appear in the tail to be differences from *Hydrosaurus lesinensis* in the relatively small development of the neural spine, which never extends upward as a broad plate in this form, and, when it does exist, is a slender backwardly-directed process. The earlier chevron bones in the present fossil appear to have been relatively broader; and in the absence of any indication of transverse processes, it is impossible to affirm that those processes existed.

The pelvis is imperfectly seen on both sides. The ilium extends on the right side parallel to the vertebræ (fig. 1, I), but its anterior part is covered by the head of the femur. The part exposed is fully 7 millims. long; its outer edge is rounded; it expands anteriorly a little, but appears to be distinguished by its slender form and parallel sides. On the left side of the specimen, underlying the other femur and articulating with a bone in front, which may well be the articular part of the ilium, is a curved bony element (nearly 8 millims. long, wider than the ilium), which from its position might well be the ischium. The bend in it occurs in its anterior third; it is comparatively slender, and only expands a little at its distal end. The slender form of the ilium and its relative length are points of difference from the species with which this has been compared. Both hind limbs are fairly well preserved. The femur of the left side (fig. 1, *m*) is about 11 millims. long, a good deal constricted in the middle, and flattened and expanded at the distal end, which is concave from side to side; the anterior margin of the bone is concave in length, while the posterior margin is more straight. The characters of the articular head are not well defined, owing to the way in which the bone is compressed; but the head appears to have been well rounded, and to have measured about half a centim. from front to back. There are no indications of the distal epiphyses represented by Kornhuber.

The tibia (fig. 2, *t*) has its anterior margin straight, and its posterior margin concave. It is about 7 millims. long. The proximal end is greatly expanded; and the shaft is relatively more slender than in Kornhuber's species. The fibula (fig. 2, *f*) is a rather more slender bone, without any indication of proximal expansion; it widens at the distal end to 3 millims., which about corresponds to the proximal width of the tibia. The tarsal bones (fig. 2, *ts*) are not well preserved, but appear to consist of one large bone below the tibia, which is apparently polygonal, and two smaller bones placed below the fibula; but there has probably been at least a third bone, which was distal in position and is not preserved. The metatarsus (fig. 2, *mt*) is not very distinct; and it is difficult to say whether the metatarsal bones were entirely distinct from each other. The specimen would appear to indicate that there were at least three metatarsals. The bone below the large tarsal element is short and broad, reminding one in its proportions of that of a Plesiosaur. It articulates by a large proximal facet with the large tarsal bone, and by a small facet at the proximal end with the distal tarsal element adjacent to it. Its width at the proximal end is over 2 millims.; and it appears to be about 4 millims. long. The metatarsals on the outer side are not preserved. There are five digits (fig. 2, I–V) formed of slender bones with a median groove on the dorsal surface of the first row. There are two bones in the first digit, which is short and terminates in a pointed bone, the distal end of which is a little curved and apparently carried a claw. There are three bones in the second digit, which is about twice the length; but the fracture in the slab passes through the middle of the terminal small phalange. In the third digit there may have been four phalanges; but the fracture passes through the third, which is so large that it is not likely to have carried a claw. There appear to have been four phalanges in the fourth digit; and in the fifth the number cannot be satisfactorily determined; but there do not appear to have been more than three. The three inner digits have the proximal surfaces of the proximal row of bones in the same line; but the two outer digits look as though placed a little higher up, which is in accord with the ordinary Lizard plan. The total length of the longest digit as preserved is about 9 millims.; and the total length from the proximal end of the tibia is a little over 21 millims. It will thus be seen that the tarsus and digits differ considerably from those indicated by the animal described as *Hydrosaurus lesinensis*.

It is of course with this type that the present specimen must be chiefly compared; and the form and proportion of the dorsal vertebræ, the mode of articulation of the ribs, and the characters of the caudal vertebræ, especially in the neural spine and transverse process, indicate a distinct type. The pelvis is also distinct, while the proportions of the segments of the limb differ in as remarkable a way, and necessitate placing this fossil in a distinct genus. Though, from the imperfect preservation of the specimen, its more important characters remain unknown, it may be conveniently distinguished as *Adriosaurus Suessii*. Its affinities need the assistance of more perfect remains for their elaboration.

I am indebted to Prof. Suess for the opportunity of making this ecord, and adding another species to the Secondary representatives f the lizard group.

EXPLANATION OF PLATE IV.

Fig. 1. Tail of *Adriosaurus Suessii*, natural size: I, ilium; *m*, femur.
2. Hind limb, from right side, enlarged: *t*, tibia; *f*, fibula; *ts*, tarsus; *mt*, metatarsus; I, II, III, IV, V, digits.

DISCUSSION.

Mr. HULKE said that he had no doubt that the species described by Prof. Seeley belongs to a genus distinct from *Hydrosaurus*. He compared the former with the Geckos in respect of their having bony scales.

The AUTHOR stated that the distinction of the vertebræ had been rendered difficult through chemical action. He doubted as to the existence of scutes in the specimen.

6. *On the* Terminations *of some* Ammonites *from the* Inferior Oolite *of* Dorset *and* Somerset. By James Buckman, Esq., F.G.S., F.L.S., &c. (Read June 23, 1880.)

During the progress through the press of D'Orbigny's 'Paléontologie Française, "Terrains Jurassiques," I was busily engaged in collecting the fossils of the Inferior Oolite and Lias in the neighbourhood of Cheltenham. In both of these rocks I had the good fortune to find a somewhat large series of Ammonites, the greater proportion of which I could readily identify from D'Orbigny's figures*.

But as these fossils were in bad condition, especially when compared with the French drawings, I was at first almost led to think that these latter had been somewhat unjustifiably made up or, as we should say in plain English, "fudged."

Thus, in reckoning up the plates of admitted Inferior Oolite Ammonites in the 'Paléontologie Française,' we find them to be thirty-eight, out of which no less than twenty species (a little over two thirds of the list) are drawn with the mouth of their shells more or less perfect; and yet, strange to say, I do not recollect a single example of their Cotteswold prototypes having occurred to me in this perfect condition.

Since those days of scepticism, however, D'Orbigny's book has become my constant and trusted companion, as the specimens in our Dorsetshire list of Ammonites appear to be in much the same condition as those figured by that talented author.

During the last seventeen years my lot has been cast in the pleasant county of Dorset; and, curiously enough, the farm that I have occupied is situate on the Inferior Oolite; the Halfway-house quarry is within a mile of my own residence; whilst a quarry in one of my own fields, within a hundred yards of my house, has proved to be one of the richest in England, if not in the world, in Oolitic fossils, and especially in the species of the Cephalopoda and Gasteropoda, in each of which great classes we may safely reckon as many as from sixty to seventy species. From this quarry and the surrounding district, there have been determined as many as twenty-eight species of Brachiopoda; and I probably possess nearly, if not quite, a hundred forms of Lamellibranchiata, which, not to name other remains, cannot but be considered as a goodly list.

If, again, we consider that the greater part of the individuals of these lists occur in a bed varying from 2 to 3 feet in thickness, the surprise becomes still greater; and not only are the species so numerous, but it is one mass of specimens, as, instead of our merely finding an Ammonite here and there (as in the Cotteswolds), this particular bed is a mass of them, so that several species will be huddled together in a small space; and, in so far as the Ammonites are

* The part on the "Céphalopodes" was finished in 1849.

concerned, on the same slab will be representatives of several of the *zonal* divisions of different authors. This may be judged from the fact that on the surface of slabs from this bed other Ammonites besides the following have been noted.

Ammonites jurensis, *Ziet.*	Ammonites Gervillii, *Sow.*
—— Sowerbyi, *Miller.*	—— Brongniarti, *Sow.*
—— Humphriesianus, *Sow.*	—— subradiatus, *Sow.*
—— Braikenridgii, *Sow.*	—— læviusculus, *Sow.*
—— linguiferus, *D'Orb.*	—— discus, *Sow.*
—— Sauzei, *D'Orb.*	—— Parkinsoni, *Sow.*

Some species prevail to such an extent that hundreds of individuals may be found in a square yard of the bed, one species prevailing at one quarry, and another at other quarries.

So numerous are individuals in some quarries, and so varied do they seem, that it is hardly possible to escape the conclusion that the family must have hybridized to a considerable extent. Anyhow, under such circumstances, it is exceedingly difficult to accurately define species—much more so than in the Cotteswold district, where it would be difficult to find more than half a dozen forms in a day.

But besides this, when we compare the Dorset and Somerset Ammonites with the Gloucestershire forms, we find that the former are usually sharp and well preserved, while the latter are considerably rougher and more fragmentary. Thus it is that shells with their terminations are rare in the latter county, while with us they are comparatively common.

The specimens laid before the Society are a sufficient evidence of this fact; and they are fast increasing, now that this matter is being more carefully investigated, the truth being that collectors seem to have vied with each other in squaring up the mouths to make them neat and tidy. Many among them, indeed, would cut away *all* of the outer chamber, preserving only the inner chambers, which, being more or less filled up with carbonate of lime, were said to be *alive*, whilst the outer one, filled up with indurated mud, was pronounced to be *dead*, and so was removed as useless.

But not only do we find our Dorset specimens to be much like the French ones (as figured by D'Orbigny) in condition and state of preservation, but the species from the two sides of the Channel are almost identical: thus we have within *four* of the whole of D'Orbigny's figured specimens from the Inferior Oolite of France.

But, besides this, there are several species in our own Cephalopoda-bed, now admitted to be high up in the Inferior Oolite, which D'Orbigny has allocated to the Lias. This, we take it, has been mainly due to the fact that this bed has been confounded with the one at the base of the Inferior Oolite in Gloucestershire.

In this list are the following:—

Ammonites insignis, *Schübl.*	Ammonites Germaini, *D'Orb.*
—— variabilis, *D'Orb.*	—— jurensis, *Ziet.*
—— Murchisonæ (?), *Sow.*	—— cornucopia, *Young & Bird.*
—— discoides, *Ziet.*	—— torulosus, *Schübl.*

Now as to the forms which up to this time we have found with terminations to their shells, we may state that as yet we have only met with fourteen; but it happens, as a rule, that the species so distinguished number several individuals, though some three or four of them have only yielded single specimens.

Our list, then, includes the following species:—

Terminations.	
Lanceolate	1. Ammonites concavus, *Sow.*
	2. —— subradiatus, *Sow.*
	3. —— Edouardianus, *D'Orb.*
Ovate-lanceolate or spathulate.	4. —— Braikenridgii, *Sow.*
	5. —— linguiferus, *D'Orb.*
	6. —— Sauzei, *D'Orb.*
	7. —— Martinsii, *D'Orb.*
	8. —— subcostatus, *Buckman, MS.*
Delphinulate, semicircular.	9. —— Gervillii, *Sow.*
	10. —— Brongniarti, *Sow.*
	11. —— Manselii, *Buckman.*
Waved............	12. —— Humphriesianus, *Sow.*
	13. —— Moorei, *Lycett.*
	14. —— boscensis, *Regnès.*

Here, then, we have given fourteen species of Ammonites with their terminations more or less complete; and for these we have attempted to make a provisional classification.

So far as we have been enabled to examine these more complete specimens of Ammonites, we arrive at the conclusion that the terminations to the shells are capable of greatly aiding in the determining of species, as trimmed-up examples of *A. linguiferus*, with their broadly oval or spathulate mouths, are difficult to distinguish from *A. Humphriesianus*; but when we have the semicircular rugose mouth of the latter for comparison with the former the difficulty vanishes. Thus, again, the lanceolate termination of the discoid *A. subradiatus* is very different from the spathulate or ovato-lanceolate ending of *A. subcostatus* (Buckm.); and yet these two forms have been referred to one species by different authors.

The dephinulate mouth in *A. Gervillii* is a complicated termination when compared with the plainer semicircular terminations of *A. Brongniarti* and *A. Humphriesianus*; and yet without this knowledge we had always confounded the first two forms.

From these remarks it seems but reasonable to conclude that the terminations of Ammonites may become important in the distinguishing of species, though, from what we have seen, their preservation is of somewhat rare occurrence; at the same time our own experience seems to point to the fact that many fine examples of more complete shells have been lost from the want of due observation upon the subject. We may further mention that, with the vast numbers of Cephalopada which are everywhere around us and which are so perfect in other respects, we have not yet seen a single example either of *Rhyncholites* or *Trigonellites*. Mr. S. P. Woodward, however, has figured an Ammonite with the operculum from Dundry*. The shell

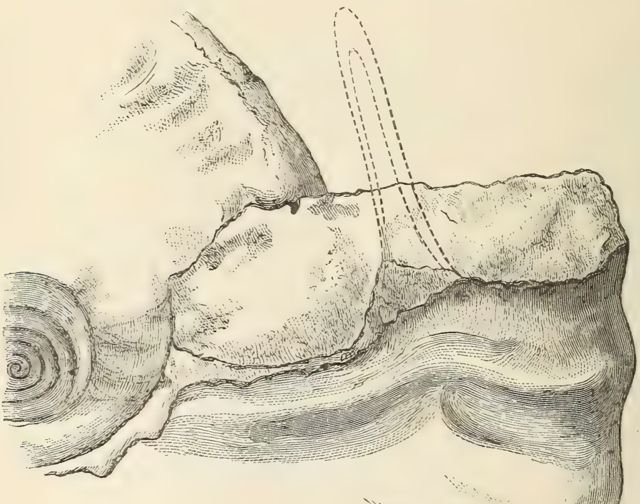
* See 'Geologist,' vol. iii. p. 328.

is referred to *A. subradiatus*; but it is very different from that which is now recognized by this name,—*A. Brightii*, which it is said to resemble, being an Oxford-Clay fossil, while the Dundry Oolite is the exact equivalent of the Dorset Cephalopoda-bed. I hope therefore some day to see this specimen in its place at the British Museum.

I now proceed to pen a few notes on these fourteen forms which we have observed to present more or less perfect terminations to their shells; and in doing so I would express the hope that ere long other forms will be met with to enable us more clearly to understand the value of a more complete structure, while at the same time it may not be too much to express a hope that better specimens may yet be found than those we already possess or, through the kindness of friends, have had access to.

Notes on the Species.

Fig. 1.—*Termination of* Ammonites concavus, *Sow.*

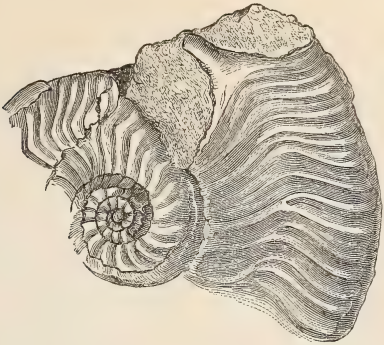


1. Ammonites concavus, Sowerby, pl. 94, fig. 2. (Fig. 1.)

This is a very common shell in the Cephalopoda-bed in Dorset and Somersetshire, occurring less frequently in the same horizon in Gloucestershire. It is a very variable shell; and hence its synonyms are unusually numerous.

In this district we have usually named it *A. subradiatus*; and it is here only retained because *A. concavus* was figured by Sowerby from a specimen obtained from this neighbourhood.

Fig. 2.—*Termination of* Ammonites subradiatus, *Sow.*



2. A. SUBRADIATUS, Sow. pl. 421. fig. 2; D'Orb. pl. 118. fig. 3 (now 1 & 2); also D'Orb. pl. 129. fig. 3. (Fig. 2.)

The difference insisted upon seems to be that in *A. concavus* the curved radii are seldom branched, whilst in *A. subradiatus*, the radii are either branched or have short intermediate ones between the longer ones. There is, however, so much variation in this respect that we still hold these to be mere varieties.

We have now several complete examples of the termination; but the first specimen was obtained by Captain Kennedy from our own quarry so perfect that it might have sat for the portrait given by D'Orbigny, pl. 129. fig. 3. It is a very common fossil, and in some quarries occurs mixed with the former so thickly that hundreds of examples could be got in a day; and yet a specimen with even the base of the termination is very rare.

3. A. EDOUARDIANUS, D'Orb. pl. 130. figs. 3–5.

Is found sparingly with the examples just quoted. Our two specimens are the only ones we have meth wit in the Bradford-Abbas quarry; and, curiously enough, they have both indications of the termination.

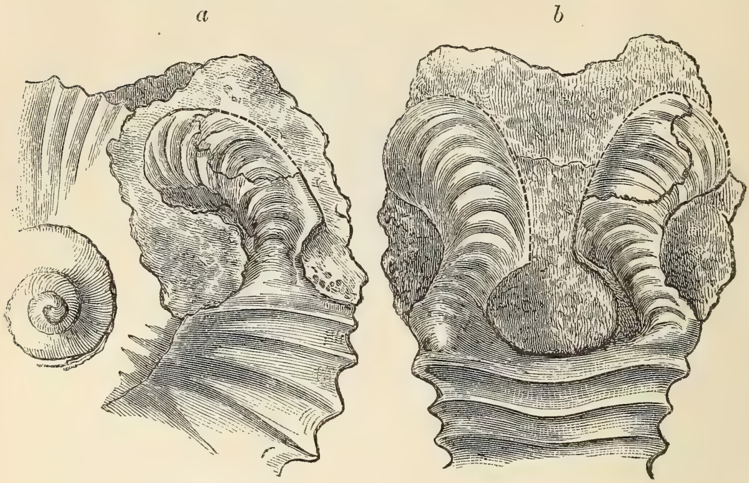
4. A. BRAIKENRIDGII, Sow. Min. Conch. t. 184. (Fig. 3.)

This shell was figured by Sowerby in the second volume of Min. Conch., which bears date 1818; the specimen, a very imperfect one, was from Dundry, near Bristol. In his description he has the following remarks*:—

"Perfect terminations of the Ammonites are scarce. I have, however, met with several specimens indicating the form of the lip; but none of them exhibit much out of the usual way, excepting some French ones and those now before us: in one of the French specimens the aperture is much contracted by the lip; in another the lip forms a single arched lobe slightly bent inwards."

* Min. Conch. vol. ii. p. 187.

Fig. 3.—*Termination of* Ammonites Braikenridgii, *Sow.*



a. From the side. *b.* From the front.

Our Cephalopoda-bed is on the same horizon as the bed from which the Ammonite just quoted was obtained, Dundry being the extreme western extension of the Oolitic system which prevails in Dorset and Somerset, which latter has so much resemblance, as evidenced by fossils, to the Inferior Oolite of France.

This fossil is usually found most abundantly at Clatcombe, near Sherborne, where examples with the curious terminations are not uncommon; and it illustrates one of those cases in which a different species of the genus occurs at one quarry from that which prevails at another. It is occasionally found at Bradford Abbas, where the prevailing Ammonites are *A. concavus* and *A. Sowerbyi.*

The terminations in this species are among the most perfect, as well as the most frequently met with. The spathulate projection varies greatly both as to length and breadth.

5. A. LINGUIFERUS, D'Orb. pl. 136. figs. 1 & 2.

Has a neat form and a less broad spathulate termination than the preceding, though closing up the aperture of the shell more by reason of its bending inwards. It is thinner in the whorls; and the ribs are in threes at the back of the shell, uniting into one, with a tubercle in front. Sometimes there is an intermediate rib between a pair, with three-ribbed vaultings.

This shell is by no means so frequent as *A. Braikenridgii*, but occurs in the same places, intermixed with it.

6. A. SAUZEI, D'Orb. pl. 139. figs. 1–3.

The termination of this shell is much like the former; but its ribs are much larger, and the shell broader. It is also inclined to be unsymmetrical, and has but few whorls.

This is not uncommon with the termination both near Sherborne and at Bradford Abbas.

These three last species are admirably figured by D'Orbigny; and yet we are happy to think that our Dorset examples are quite up to the perfection of the French ones.

7. A. Martinsii, D'Orb. pl. 125. figs. 1, 2.

Is not uncommon; but the small specimen we have sent is the only case in which we have observed the terminal lip. It seems to have been the first lip formed; and if fig. 3 of D'Orbigny's plate represents the lip of an older specimen, it would tend to show that the lips vary very much with age. Our specimen is from Bradford, where the species is not uncommon.

8. A. subcostatus, Buckman, MS.

This shell, from near Sherborne, belongs to the discoid section of Ammonites, and is therefore only placed here on account of its spathulate termination, which differs so much from that of the shell with which it has been confounded, namely *A. subradiatus*.

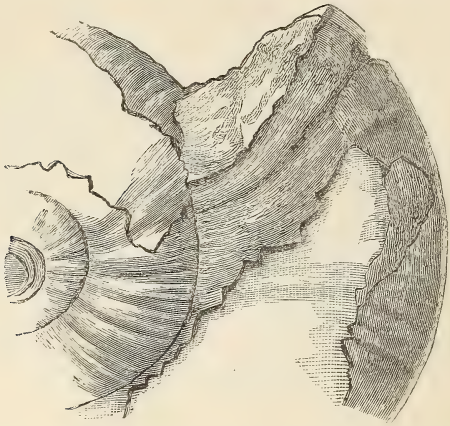
Probably this is the *A. subradiatus* of D'Orbigny, T. J. pl. 118. figs. 1 & 2.; but if so it differs so much from his *A. subradiatus* previously referrred to that we feel justified in proposing a fresh name for it. Our specimen is the only example we have met with with the termination: still it is not an uncommon fossil near Sherborne, though it occurs very sparingly at Bradford Abbas and Half-way House.

Fig. 4.—*Termination of* Ammonites Gervillii, *Sow.*

9. A. Gervillii, Sow. p. 184, tab. A. fig. 3; D'Orb. pl. 140. figs. 1–7. (Fig. 4.)

This is a shell with a very curious and interesting termination, which we have named delphinulate, because its side view is so much like that of the head of the classic Dolphin. Sowerby says, "This species occurs in a marly limestone which is replete with grains of iron ochre. It is from Bayeux, in Normandy" *.

Fig. 5.—*Termination of* Ammonites Brongniarti, *Sow.*



10. A. Brongniarti, Sow. t. 184 A, fig. 2; D'Orb. pl. 137. figs. 1–5. (Fig. 5.)

The lip of this shell is so decidedly distinct from the preceding that we cannot help separating them, although we at one time inclined to a different opinion. It is not at all so complicated, but is of a semilunar or, rather, semicircular shape, with a deep depression beneath, but without the elaborate form of the lip of *A. Gervillii.* It is met with at Bradford Abbas and other places near Sherborne.

11. A. Manselii, Buckman, n. sp.

Is perhaps related to the *A.-Brocchii* group; but the fineness of its ribs and the absence of tubercles is a sufficient distinction. We have in one single example the usual deep depression before the terminal semicircular depression. We possess several examples of this shell from Bradford, Chalcombe, and other places; but only the one sent is an example of the termination.

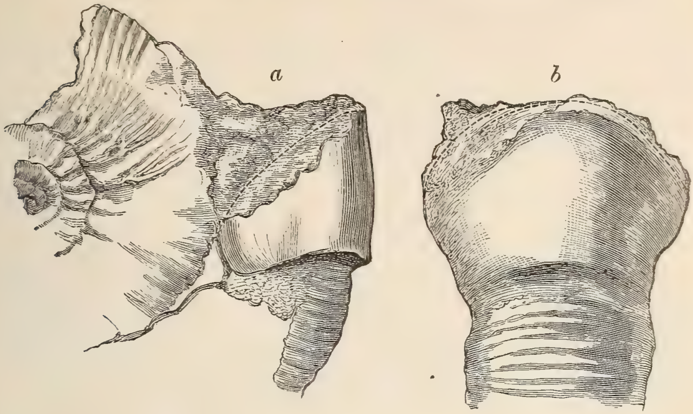
12. A. Humphriesianus, Sow. t. 500. fig. 1; D'Orb. pl. 133 & 134. (Fig. 6.)

This is a very variable shell, sometimes having few (perhaps five) thick whorls, at others from eight to ten, exceedingly slender and delicate; yet the markings are the same, and the termination of both, starting from a deeply contracted furrow, is simply semilunar in shape, and is the same in both large and small examples.

This is a common shell about Sherborne, but is rarely met with at Bradford or Halfway House.

* Sowerby, Min. Conch. vol. ii. p. 190.

Fig. 6.—*Termination of* Ammonites Humphriesianus, *Sow.*



a. From the side. *b.* From the front.

13. A. Moorei, Lycett, 'The Cotteswold Hills,' pl. i. figs. 2, 7.

The flexure of the mouth of the shell, with its elegantly curved line, like that of a modern Nautilus, is distinctive of this shell. It is common to the sandy part of our Oolite below the usual Cephalopoda-bed. The mouth is simply a termination of a flat slightly ribbed shell, without any previous depression. It is a common shell in the limestone bands below the Cephalopoda-bed; but the specimen sent is the only one in which we have observed the completion of the mouth of the shell.

Fig. 7.—*Termination of* Ammonites Moorei, *Lycett.*

14. A. boscensis (?), Reynès.

We quote this, with some degree of hesitation, from Beneke, inasmuch as we have only a single specimen. This, however, is from the Cephalopoda-bed of Bradford Abbas, and in some points it is so much like the *A. Moorei*, both in its form and the outline of the mouth, that even now we must confess to feeling great difficulty in the matter.

Note.—Since the above was in type, we have found other species and examples with terminations. These, with the new forms, will described in a paper now preparing for the Society

Discussion.

Mr. Charlesworth called attention to the early work in this direction of the late Mr. Chaning Pearse, who studied the Ammonites of the Oxford Clay of Christian Malford. That author was led to believe that the peculiar prolongations of the mouth were periodically absorbed and reproduced.

7. *On* Abnormal Geological Deposits *in the* Bristol District. By Charles Moore, Esq., F.G.S. (Read November 17, 1880.)

In making excavations at Redland, on the edge of Durdham Down, about 45 years ago, some conglomerates, associated with Carboniferous Limestone, were opened up, which contained the teeth and scattered and broken bones of reptilia, described by Messrs. Riley and Stuchbury in the 'Proceedings of the Geological Society' for 1836 under the names of *Thecodontosaurus* and *Palæosaurus*. As they were then the oldest known reptilia and of a high order, much interest has always attached to them. A few years since, in drainage-works at the same spot, this conglomerate was again crossed, and some other bones added to the series deposited in the Museum of the Bristol Philosophical Society. The collection has since been reviewed and described by Professor Huxley, F.R.S.*, and an account of the physical characters of the district given by Mr. Etheridge, F.R.S.†

Much uncertainty has prevailed as to the geological age of the Durdham-Down conglomerate. At first it was supposed to be Permian; but we have as yet no conclusive evidence of true Permian beds in the West of England. Mr. Etheridge has placed it on the horizon of the Dolomitic Conglomerate of the Keuper; whilst, owing to the discovery by myself of the same genera of reptilia, under somewhat similar physical conditions, in the Rhætic deposits of Holwell, and since then of true Rhætic remains on Clifton Down, I had referred them to the latter age—a point to be reviewed below.

In my paper on the abnormal conditions presented in the Frome district I especially described numerous Secondary unconformable deposits and vein-fissures resting upon or passing down through the Carboniferous Limestone, some of them having organic remains whereby they could be referred to different geological periods. Since then I have discovered several other features of interest at Holwell; and as the phenomena of this district will serve as a key to unlock hitherto unnoticed physical conditions in the geology of the Bristol area and some of the palæontology connected therewith, it will be desirable first shortly to notice the special features presented near Frome.

The Carboniferous Limestone has here its last south-eastern exposure before being entirely covered up by Secondary deposits, and is to be seen in very narrow ravines at the Vallis, Elm, Mells, Whatley, Nunney, and Holwell. The prettiest combe is that of the Vallis, from which, at its northern end, bifurcates that which passes to Elm and Mells. At the entrance to the Vallis at Hapsford the first sections show irregularly bedded Rhætic conglomerates resting

* "On the Classification of the Dinosauria, with observations on the Dinosauria of the Trias," Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 32.

† "On the Geological Position and Geographical Distribution of the Reptilian or Dolomitic Conglomerate of the Bristol Area," Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 174.

in depressions on the edges of the inclined Carboniferous Limestone. They are separated by thin blue clays with *Avicula contorta* and also *Discina Babiana*. I have no doubt they would yield important vertebrate remains, as I found a very perfect Dinosaurian vertebra; but, unfortunately, these beds have not been worked for some years. Vertical mineralized infillings are present, passing down through the Carboniferous Limestone in this section. In the southern corner, but occupying a higher position than these conglomerates, there is a patch of close-grained cream-coloured limestone undistinguishable from the White Lias; but it has yielded me no trace of organic remains. The deposits of one section usually differ from those in another, or die out altogether, although they may be in close proximity. For instance, in the next quarry the conglomerate is a single thick, dense bed, with pebbles united by calcareous matrix, in which are occasional nests of *Estheria minuta* and insects, whilst above are a few inches representing the Lower Lias, capped by about 10 feet of Inferior Oolite.

In addition to the unconformable Secondary deposits which lie on the Carboniferous Limestone, a special feature of the latter formation is the many vertical fissures passing down through it, with infillings containing Secondary remains, or those of a still later age. In the Vallis these veins are best seen in the face of a large quarry at Eggford, where, in addition to several smaller ones, the workings are bounded by veins at both ends, that on the north being of some thickness, and showing a vertical side about 50 feet in height, where it meets a patch of Inferior Oolite. The matrix of this vein is Liassic; and numerous organisms may be traced in it. All the veins are much mineralized, and contain sulphate of barytes in concretionary layers, with occasional traces of galena and blende. At Elm and at Nunney hæmatite iron-ore has been extracted; at the latter place in close proximity to a deposit of Inferior Oolite.

The hamlet of Holwell occupies a depression at the southern end of the Vallis gorge, and is on every side surrounded by sections which, if looked down upon from a little distance, without closer inspection, would appear to most geologists to be entirely composed of Carboniferous Limestone. The road from Frome to Shepton Mallet passes through this spot, and crosses the little stream from which the hamlet is named. On the eastern side are two quarries I have already described*, viz.:—that of the Marston road, in which, within a few yards, are present stratified Inferior Oolite, Liassic conglomerate (with many organisms), and a thin band of Rhætic clay, all resting on Carboniferous Limestone, with a thick vein filled with calc-spar in their midst; and also a large quarry below, with a face parallel to the stream, in which are to be seen many vertical dykes, some with Rhætic and others with Liassic organisms †. They present much mineralogical variety; and the somewhat impure limestone

* "Abnormal Conditions" &c., Quart. Journ. Geol. Soc. vol. xxiii. (1867) p. 483.

† A section of this has been given in "Abnormal Conditions" &c., Quart. Journ. Geol. Soc., 1867, p. 484.

within the veins shows, by its frequently being in very thin laminæ, that it has been deposited slowly. It is desirable to bear in mind, whilst comparing the same facts in the Bristol district, that in the quarries above noticed the limestone of these Secondary infillings is often left standing out as butresses by the workmen, whilst they work back between them for the purer Carboniferous beds.

Postpliocene, Liassic, and Rhætic Deposits. The Microlestes-*Quarry.*—On the Shepton road, immediately west of the hamlet, there is a large quarry on each side facing the road. The first, on the south, is the *Microlestes*-quarry; in the other, inclined Carboniferous Limestone has been worked between thick veins of Middle Lias, the matrix of which occasionally showed carbonate of lead and barytes. The rubbish-tippings from the limekiln have since obliterated these points; but I have preserved them in photographs. It is probable that all the veins on this side of the hamlet differ from and are to the south of those in the large section east of the river.

In my former examinations of the *Microlestes*-quarry I was told by the workmen that they had occasionally crossed a fissure down which, by the aid of a rope, a man might descend; but, as it was becoming dangerous, it was filled up. From this I have suspected the presence of a Postpliocene cavern at the spot; but although it has not been found, they have worked back upon a vein filled with bones, which I have little doubt may be connected with one. It is about a foot in thickness, and, like all the other fissures and their infillings, appears to have its own special individuality. Like an ordinary mineral vein, the walls have vertical mineralized layers, the innermost being large crystals of dog's-tooth spar. Towards the top there are angular pieces of Carboniferous Limestone, which below give place to material composed of about one third of brown marl, crystals of carbonate of lime, and dismembered jaws and bones of *Arvicola* and frogs, with, rarely, small vertebræ of birds and fish. The jaws of *Arvicola* are very numerous, whilst their vertebræ and other bones are scarce. They appear to belong to *A. arvalis* or *A. saxatilis.* Bones of the larger mammalia, though few, including ox and deer, were found. Amongst them was found a tooth not to be distinguished by itself from a human incisor; but the subsequent discovery of the remains of wolf leads to the inference that it may belong to that animal, the difference in the incisors being with difficulty distinguished. Several Rhætic teeth, showing from their worn condition that they are derived, and a few Carboniferous-Limestone corals and shells are mixed with the above, as well as pebbles of hæmatite and bog-iron ore.

The deposit, with its Rhætic remains, was in a north-and-south fissure a little west of the above; but it is now all but exhausted. Without reference to other mineralized veins in which no organisms have been found, it will be seen that at Holwell alone, and in the line of a single quarry of but a few hundred feet length, Postpliocene, Liassic, Rhætic, and Carboniferous-Limestone formations are represented. These later deposits are the rule, not only where they

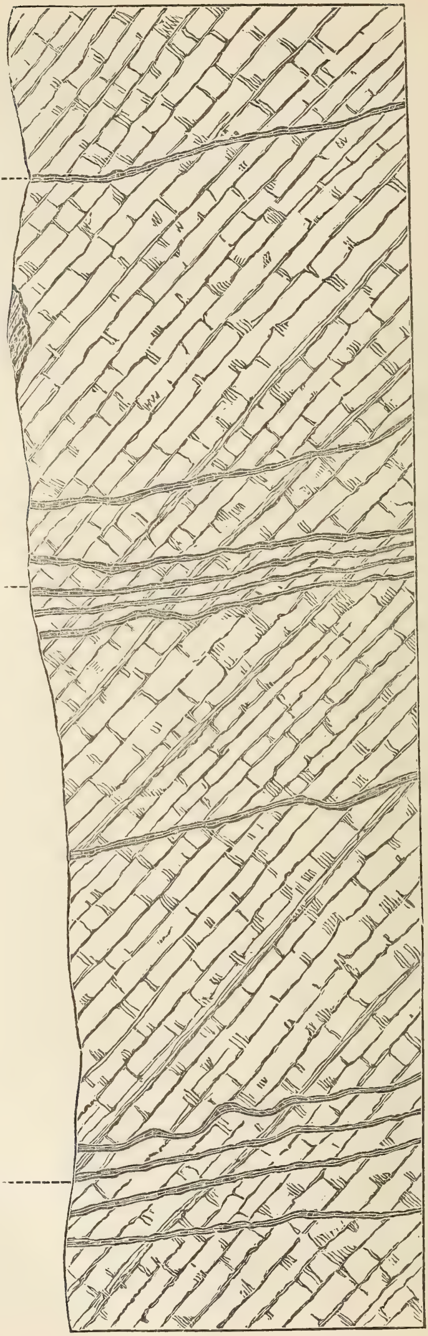


Fig. 1.—*Section at the Edge of Durdham Down.*

fringe the outcrop of the older rocks, but high up on their table-lands, as in the case of the Charterhouse lead-mine, near Cheddar.

The Bristol Area.

Before proceeding with a description of the Bristol area and comparing it with the above, it is desirable I should advert to a new palæontological feature which hitherto has not attracted any attention, in the presence of a multitude of minute *Serpula*-like calcareous tubes found in various deposits under examination. Years ago I noticed them in the freshwater brick-earth of Salisbury, which is of Postpliocene age, and put them aside as minute *Serpulæ*; but afterwards learning that all species of this family are marine, I thought they might possibly be analogous to caddis-cases, and belong to some insect. When they were afterwards found in enormous numbers, and under many diverse circumstances, I saw the desirability of learning more about them, and sent them to friends who were authorities in special departments of natural history for their opinions, at the same time describing the circumstances under which they were found. Without mentioning names, it proved a "pursuit of knowledge under difficulties." First, they were doubtfully referred to the cases of some Dipterous insect; and if not such, it would be worth considering if they were *Serpulæ*. An entomologist decided that they were not insect-tubes; a good microscopist was of opinion they were the calcareous cases left by rootlets of vegetation passing down from the surface; next, an eminent zoologist intimated, with some uncertainty, that they somewhat resembled the genus of Serpulidæ, *Filograna*; then a good botanical friend and microscopist pronounced them to be vegetable; upon which I sent them to a first-class botanical expert, who was of opinion they had nothing to do with vegetables, and that he had consulted a zoological friend, who also believed they were worm-tubes allied to Annelids, and that again they presented some resemblance to *Filograna*.

They are to be found very abundantly in some of the vein-fissures of the Carboniferous Limestone (to be referred to hereafter) in the Bristol district, and also, though not in such numbers, in some of the later stratified marls. My impression is that they are due to freshwater conditions, and that, though they may not be rootlets which have passed down from the surface (some of them being found under conditions apparently precluding this idea), yet they may, notwithstanding, be due to freshwater vegetation. They are sometimes free, but often in clusters united by the matrix of the deposit. It will be desirable to determine their systematic position, as they will have a bearing on the age and other conditions of the deposits in which they are found. I propose that they should be recognized under the designation of *Tubutella ambigua*.

Durdham and Clifton Downs.—I now propose to show that the same physical conditions prevail at Durdham Down and at various outlying spots near Bristol, as in the Frome district. The area to be first noticed will be that embraced in the southern escarpment of the Carboniferous Limestone, extending from Redland, its eastern end at Durdham Down, to the suspension-bridge at Clifton, overlooking the river Avon on the west.

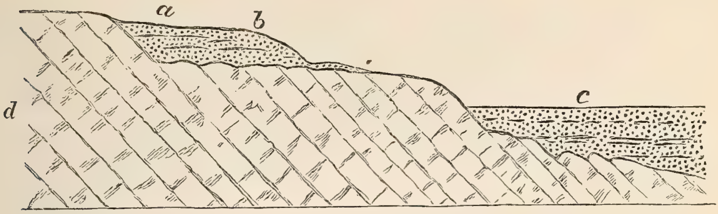
Near the Old Black Boy inn, just under the edge of Durdham Down, there are places known as The Quarry and The Quarry Steps (see fig. 1). Standing on the latter, we look down into a large excavation, which must have been formerly extensively worked for stone, but is now occupied by small houses and gardens, most of which are probably a century old. One of these houses is close under the flight of steps leading to The Quarry, and has been built against a natural vertical wall of mottled red or yellow unstratified limestone, differing altogether in colour and texture from the grey Carboniferous Limestone of the district, by which, on either side, it is bounded. It is about 8 feet in thickness, and may be traced on the east side of the excavation by its brighter colouring; and there is no doubt that it continues into the limestone of Durdham Down immediately above. As was the case with the workings on the Mendips, the old quarrymen here extracted the purer limestone, leaving the impurer somewhat conglomeratic infillings standing out, and terminated their quarry on the east by this large dyke. As it has not been opened up, little examination could be given to it for organic remains, which, from its close proximity to the Thecodont deposit, would have been desirable; but that some are present therein is sufficiently indicated by the fact that, after examining a few pounds weight of the softer material taken from the interstices or sides of the vein, I obtained numerous minute fragments of bone or teeth, one very small fish-tooth, an *Echinus*-spine, a few joints of Carboniferous-limestone Encrinites, and some of the tubes previously referred to.

The platform of the Quarry Steps rests upon the surface of the above dyke. Looking from it, along the Down escarpment to the west, the eye takes in Bellevue Terrace, on the edge of the Down; and it was between these houses and the quarry, a distance probably of 200 yards, along the same face of limestone and on the same horizon, that the deposit containing the Thecodontosaurian remains was found. Unfortunately the precise spot is unknown; and, from its being built over, there is not much hope of its being again identified.

My late friend, Mr. W. Sanders, F.R.S., of Clifton, gave me, some years ago, a sketch showing the conglomerate on the edge of the limestone, with what was then considered to be New Red Sandstone at its base (fig. 2); and it is significant that he does not so much represent it as a basin-shaped depression in the limestone as indicate a deposit following the slope of the escarpment, similar to the case of a vein the top of which was opened up, but from which the limestone still resting below against its side had not been removed. Mr. Sanders also marks the spot where the reptilian bones were supposed to be found.

At the time when these reptilia were discovered, the peculiar conditions of deposition I have indicated were unknown. In the

Fig. 2.—*Sketch Section of the* Thecodontosaurus-*bed of Durdham Down.* (Drawn by W. Sanders, Esq., F.R.S.)



a. Conglomerate of New Red Sandstone.
b. Locality of *Thecodontosaurus.* *c.* New Red Sandstone.
d. Carboniferous Limestone.

section described below, which embraces a line of working from the Quarry Steps to a large quarry which I call the "Avenue Quarry" (from its being immediately north of the Avenue Road), a distance all together of about 680 yards, I shall show the presence, as at Holwell and elsewhere, of a series of veins with infillings derived from different geological ages; and my interpretation of the reptilian deposit therefore is that it is one of such a series in Carboniferous Limestone, by which, on both sides, it is surrounded.

Durdham Down Section.—From the Quarry Steps to the end of Bellevue Terrace, within which area the reptilia were found, is about 300 yards. Until lately these were the last houses fringing the Down to the west; and there then stood up by itself, like a wall, a large vein-infilling (the limestone having been worked up to it on both sides) separating the garden of the last house from an adjoining quarry. Other buildings have now occupied the line of the quarry, covering up four smaller veins; but the one above referred to, from 14 to 16 feet in thickness, is still utilized as a boundary between the gardens. It has the same general lithological character as that at Quarry Steps, but has occasionally small pockets of iron-ore, and is more mineralized. I purposed to examine these veins closely for organisms, but have been prevented.

Passing along the roadway from this quarry, the next vein seen was one containing hæmatite iron-ore, at its thickest about 16 feet. It had been worked up to the roadway on the edge of the Down. At my last visit this also was being filled up, and a house built across it.

Alluvial Veins with Liassic and Rhætic Remains.—For about 200 yards from the iron-ore vein the limestone has been unworked. Following the road to a spot near the ventilating-shaft of the Avonmouth Railway, an archway facing the road leads into the Avenue Quarry, which presents some interesting features. For many years a lump of seemingly stratified yellow marl had been left in the bottom of the quarry, the limestone having been worked around it. Its presence often puzzled me; but there is little doubt that it is due to an alluvial infilling into a small limestone cavern, and is connected with one of three thin veins of alluvial material which are present in this quarry. A cavern was many years ago discovered on the Down, containing, amongst other things, the remains of *Hippopotamus*, which are now in the Bristol Museum. These three veins are filled with an ochreous or brown clay, which, when critically examined in its natural condition, appears to differ slightly in character in each, as though they might have received their infilling at somewhat different times; still, to save labour in the examination of their contents, they were mixed together. Their organic remains are very varied, and not less so their mineral constituents. Their Postpliocene or still later age is indicated by the presence in them of frequent portions of the incisor teeth of *Arvicola*, and a single shell of *Helix*. Although all the remains are rare, those from the Lower Lias are most abundant. These consist of young forms of *Ammonites* of two species, *Myacites* and *Astarte*, *Cylindrites* and portions of three other univalves, a Pentacrinite-stem, and a single valve of an Entomostracon. There are teeth and scales of fishes, and a fragment of bone which may be either Liassic or Rhætic. The interesting presence of Rhætic remains, however, is shown by teeth of *Saurichthys* and *Lophodus* and a small palate identical with species from Holwell. Some of the teeth are bleached and worn by water-erosion. The little calcareous tubes accompany them.

The residue of these veins, after washing, shows a great abundance of black pisolitic granules. The following analysis of its mineral contents has been obligingly made by Mr. Gatehouse, City Analyst of Bath:—

Soluble in acids:	
Water	7·80
Calcium carbonate	20·50
Magnesium carbonate	0·73
Oxide of iron	6·50
Zinc carbonate (calamine)	0·54
Manganese dioxide	0·50
Lead-sulphide (galena)	0·90
Silica	8·16
Alumina	2·60
Potassium	0·07
	48·30
Insoluble in acids:	
Calcium sulphate	0·39
Silicate of zinc	0·25
Oxide of iron (insoluble)	6·55
Alumina "	10·45
Silica "	33·70
Copper	trace
	99·64

Liassic Vein.—The working of the limestone in this quarry has terminated on the western side against a vein from 10 to 12 feet thick, which has received an infilling of yellow clay of an entirely different lithological character from those last mentioned. So far as the evidence goes, it is apparently a vein of true Lower Lias, with occasional weathered blocks of Carboniferous Limestone. All the remains found are Liassic, and consist of:—

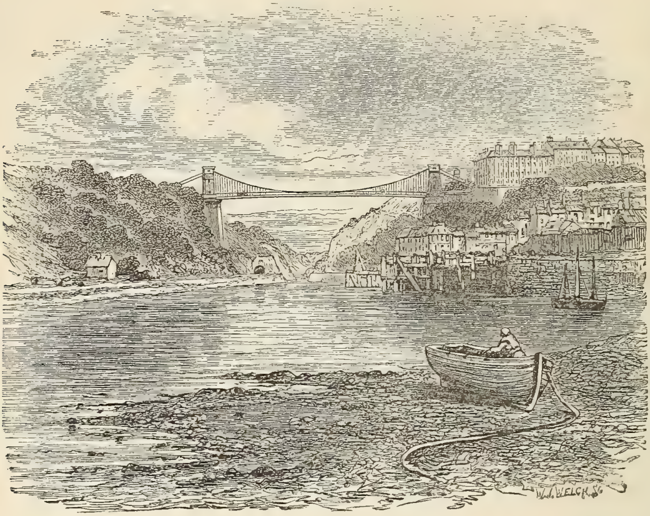
Teeth and scales of fishes.	Gryphæa.
Ammonites (young).	Terebratula.
Univalves (several species).	Cidaris (teeth, plates, and spines).
Astarte.	Pentacrinites.
Modiola.	Cristellaria.
Lima.	Webbina.
Cardium	

All the phenomena I have mentioned, from the Quarry Steps to the Avenue Quarry, are embraced in less than half a mile. Without including the Reptilian deposit, eleven veins are shown to be present; and but for a considerable part of the edge of the Down being covered, no doubt many others would have been seen.

The Rhætic Bone-bed.—There are no workings between the Avenue Quarry and the neighbourhood of the Clifton suspension-bridge. The road to the latter is cut through Carboniferous Limestone containing many veins, which are usually filled with calc-spar and other mineralized matter. Looking towards the Observatory, there are two veins. One, filled with limestone, has been left boldly standing up by the quarrymen; but nothing can be said of its age. Close to the toll-house, however, on the Clifton side, there is a deposit of considerable interest, having a face of about forty feet, in which the Rhætic bone-bed and its associated remains are present. It is partly composed of irony and yellow sandy-looking marl, with many free crystals of carbonate of lime, as in the Holwell fossiliferous infilling; and there are also patches of finely laminated rock, similar to the Rhætic "White Lias." Some of the associated blocks of stone appear to be fossiliferous; but as the deposit forms the boundary-wall of the toll-house, they cannot well be broken down for examination. The bone-bed is two inches thick, with teeth of *Saurichthys apicalis*, *Lophodus minimus*, and many fish-scales; and the clay on either side contains fish-remains of the same age.

In Professor Ramsay's 'Physical Geology and Geography of Great Britain,' he has given a very pretty sketch of the Gorge of the Avon, with the Suspension-bridge and its beautiful scenery, which, through the kindness of Prof. Ramsay and of Mr. Stanford, the publisher, I am permitted to use (fig. 3). Curiously enough, it includes the Rhætic bone-bed, and, on the shoulder of limestone looking down the river on the east, the conglomerate mentioned below. The Carboniferous Limestone dips rapidly to the south under the Bedminster coal-beds, and disappears under beds of New Red Sandstone. A lighter line in the sketch, between the eastern abutment of the bridge and the houses on the level of the roadway, with the Observatory seen beyond it in the distance, shows the exact position of the Rhætic deposit.

Fig. 3.—*Gorge of the Avon at Clifton.*



Before referring to other outlying sections near Bristol, it may be noticed that although the true New Red Marls are present around, the red and variegated marls which lie on the east of the basin between the Durdham-Down and Clifton escarpment, and extend towards Bristol, are alluvial. They have been opened up in brick-pits repeatedly, as well as the conglomerates below. From the former, after long search, I obtained several small bits of Inferior Oolite and fragments of shells of *Ostrea*. The conglomerates are bedded, and are usually extracted on the site of each building erected; and although hundreds of thousands of tons have been so used, I have never detected any contemporaneous organism in them, nor have I heard of such having been found. They get coarser and more irony as they approach the limestone below; and in several sections its rugged surface has received pockets of hæmatite iron-ore. The pebbles are comparatively small and angular, and give the idea that they may be due to a subaerial denudation of the Carboniferous tableland above.

Conglomerate of the Avon Gorge.—Passing down the river, not far below the Suspension-bridge, the "Dolomitic Conglomerate," of which Mr. Etheridge has given a section, is reached. It rests on the edge of the Carboniferous Limestone at the side of the road leading up to the Down, and is, as a friend has remarked, "a gigantic heap of conglomerate" with pebbles of great size at the base, getting gradually smaller at the top. It is very irony, and appears to occupy but a small area. Some red marls gathered from the sides and interstices of the deposit yielded me part of a fish-palate, which is probably of Carboniferous-limestone age, and great numbers of Encrinital stems, a comparatively recent freshwater operculum, and numerous examples of *Tubutella*. Whatever may be the age of this deposit, groups of the latter are usually surrounded by an irony matrix which seems part thereof.

Vein at Ashton.—On the west side of the Avon, about a mile beyond Ashton, considerable deposits of iron-ore occur; but I have been unable to examine them. They lie at the foot of the limestone escarpment. On the tableland above them, at Longwood Farm there are disturbed Carboniferous Limestones, in which a vein occurs containing occasional lumps of galena and some calamine. *Tubutella* is present in great abundance. The upper part of this vein is somewhat honeycombed; and the tubes are found adhering to thin flakes of calc-spar. No other organisms were found at this spot.

Westbury-on-Trym—Carboniferous Limestone with Minerals and Oolitic Remains.—On passing from the Durdham-Down quarries (previously mentioned) along the eastern edge of the Carboniferous Limestone, at a distance of two miles, some large quarries are to be found. On the eastern side of one at Southmead, worked by Mr. Kennedy, there may be seen what appears to be an ordinary mineral vein, about a foot thick, passing down through the section. It contains good hæmatite iron-ore, ochre, galena, and calamine. Although it appeared nothing but a mass of mineral matter, I still hoped a sample might yield some evidence of its age. In this I succeeded beyond my expectation; for on washing it I at once found many angular pieces of Inferior Oolite, which, from their being stained with iron, were not before visible. On a still closer examination I obtained the oolitic organisms given in the list below, associated with *Tubutella*; the specimens show very little sign of attrition. No Oolitic deposit from which they could be derived, however, is in this district nearer than Dundry, six miles to the south, or the Cotteswolds, many miles to the east, with, in the latter case, the area of the Bristol coal-field intervening.

In the same quarry there is at another spot a pocket of light-green clay. Although very intractable, I was able to disintegrate it sufficiently to find that it contained Algæ &c.; and although there remains a little doubt as to their age, it is likely they are of comparatively recent date.

Westbury vein, Oolitic Organisms.

Fish-tooth.	Thecidium.
Nerinæa.	Bryozoa, several species.
Solarium.	Echini, teeth, plates, and spines.
Univalve, sp.	Entomostraca.
Turbo.	Serpulæ.
Dentalium.	Foraminifera ?
Astarte.	Tubutella.
Cardium.	Pentacrinite joints.
Ostrea.	Encrinite stems, Carboniferous.

Algæ (in clay vein), several genera

The sections remaining to be noticed are along the eastern edge and to the north of the Bristol coal-field. On the eastern side the Carboniferous Limestone does not come to the surface between the Mendips and a very small outcrop at Grammar Rock, under Lansdowne, near Bath (which is not recorded on the Ordnance Map), and others at Wick Rocks and Codrington. From Chipping-Sodbury a narrow belt continues to Yate snd Wickwar, and entirely surrounds the north of the coal-basin.

At Wick, where the quarries are extensively worked, mineral veins are to be seen having their usual vertical bands of barytes, galena, &c. passing down them. In their softer pockets *Tubutella* is abundant; in one which has a marly infilling it is present in great numbers. Occasionally small patches or pockets of grey marl lie near the surface; but I have not yet found any other organisms in them.

The Yate Rock Sections.—These are between Chipping Sodbury and Wickwar. On the ragged surfaces of the limestone there are here also pockets containing more mineralogical materials with *Tubutella.* A vein passes down from the surface of one of the quarries a foot in thickness, containing soft mineralized material in which are myriads of these little tubes; they are often attached to the broken-up pieces of barytes and other minerals.

Nettlebury Quarry, Yate, and Clevedon.—The Nettlebury quarry is a large one, nearest Wickwar, and is the last I shall refer to on this side the Bristol coal-basin. A section of it has been given by Mr. Etheridge *, in which are shown to the east horizontal step-like beds, overlying highly inclined Carboniferous Limestone, whilst on the west side equivalent beds dip at the same angle as the limestone towards the coal-basin. At the present time it would be difficult to recognize the locality from the above section, from the almost entire absence of the beds on the eastern side, though they are present from 12 to 14 feet thick on the west. Mr. Etheridge considers these beds to be of the age of the Dolomitic Conglomerates, and the representatives in lithological condition and age of the supposed Magnesian Limestones of Clevedon. The latter are thick, irregularly bedded, yellow limestones, used in the district for building-purposes. It is apparently a local deposit, resting in the quarry near the hotel on Old Red Sandstone, which crops out on the beach and abuts against Carboniferous Limestone to the east, the Old Red being fringed on a level with the Severn by a continuous belt of Dolomitic Conglomerate, continuing north for some miles. Almost every parting or crack between the blocks of Clevedon stone shows the presence of galena, carbonate of copper, or other minerals. In only one instance have I found a block of stone with organic remains. This contained a few Encrinital stems, an imperfect *Rhynchonella*, and also several imperfect *Strophomenæ*. Were it not that the specimens put on the lithological appearance of the enclosing matrix, I should be disposed to think them redeposited

* Quart. Journ. Geol. Soc. vol. xxvi. (1870), p. 179.

from the Carboniferous Limestone *." Looking at the Yate deposit as it lies on the limestone in the section, it has much resemblance to the Clevedon beds, but on closer examination this ceases. The latter are almost pure Magnesian Limestone, whilst the upper 9 feet of the former are of sandy yellow marls, which on being washed float away and leave a sandy residue. Next follow eighteen inches of yellow limestone, in two irregular beds, which in structure and colour somewhat resemble the Clevedon stone. On treatment with acid these also leave a sandy residue. Between the above and the Carboniferous beds there is a thin deposit in pockets, almost composed of fine grey sandstone. There are no organic remains special to these beds beyond fucoids and *Tubutella ambigua*, which is rare. For these reasons, and knowing how varied are the deposits on the outcrops of the older limestones, I am disposed to think that the yellow beds at Yate are of comparatively recent age. On the surface of the Carboniferous Limestone there are occasional thin patches of what appears to be a comminuted shelly breccia with a grey sandy matrix, which I do not think the equivalent of the bouldered Dolomitic Conglomerates found in other parts of the district.

Thornbury Railway and Secondary Veins.—The branch line which leads from the Yate station to Thornbury exhibits some interesting geology. At Tytherington fine sections of Carboniferous Limestone are seen, and thick deposits follow of what are, no doubt, true Dolomitic Conglomerates. On emerging from the tunnel towards Thornbury these have some marly divisions, in which, in a flat over the tunnel, some galena has been found. Not far beyond, the Lower Limestone shales pass into the Upper Devonian beds, the conglomerates also resting upon them. Just before reaching this point there are several thin veins in the limestone containing sulphate of barytes and galena, in a matrix of gossany iron-ore. A sample from the soft ochreous part yielded me three Conodonts of Carboniferous-limestone age—and of Secondary remains, Pentacrinite joints and a single specimen of a Foraminiferous shell, *Planularia pauperata*. On a second visit I discovered deposits towards the surface which, lithologically, I cannot distinguish from a ferruginous marl of the Middle Lias, which contains hollow casts of shells and crushed specimens of what appear to be *Rhynchonella tetrahedra*. *Tubutella* is present in great numbers, surrounded, as at Yate Rocks, by a re-deposited ferruginous matrix.

Age of the Deposits.—From the foregoing examples of abnormal deposition, all of which have been accidentally revealed by quarrying-

* Since writing the above, I have sent the specimens to my friend Mr. Davidson, who says:—"The specimen you send for my examination you say is from the Magnesian limestone. In colour it looks like a rock of that formation; but I have never hitherto seen from our British Permian rocks a *Strophomena* or *Streptorhynchus* shell similar to the one I observe on both sides of the specimen, and which looks like *Strophomena crenistria*. The *Rhynchonella* is not sufficiently complete for specific determination. If not Carboniferous, at least one of the species would be new to our Permian rocks or Magnesian Limestone. I almost fear your enclosed specimen is Carboniferous."

operations in the Carboniferous Limestone, it must be manifest that there are a multitude of other examples not yet opened up that would yield an interesting study to the geologist. One of the most difficult problems regarding some of them is to arrive at satisfactory conclusions as to their exact age; but there can be little doubt that the physical conditions to which the deposits are due were the same both in the Bristol and the Mendip areas. Supposing the fissures in any district had all been caused by the same shrinking or change of level, they would have been subject to the same refilling influences, and would contemporaneously have received a mixture of materials derived from the denudation of that time; but although the alluvial infillings in the Avenue Quarry have a mixture of organisms, it is a singular fact that in a series of parallel veins coming to the surface on the same horizon, not far removed from one another, and some of them but a few inches in thickness, each appears to have an individuality of its own, and to represent in geological time intervals clearly distinct from one another. As at Holwell, so at Durdham Down, the worked face of the escarpments reveals infillings of alluvium, Oolite, Lias, and Rhætic and Keuper beds, whilst mineralized or iron-ore veins show conditions specially their own.

Reference has repeatedly been made to the *Tubutella ambigua*, which I have found in almost every deposit that could be examined under favourable conditions, from Maidenhead to those of Gloucestershire and Somersetshire. When they occur, as in the brick-earths of Salisbury, in association with freshwater shells, and also with Postpliocene mammalia, there seems little reason to doubt that they belong to freshwater deposits. If they can be traced in older formations, they may be a guide in determining the conditions under which those formations have been laid down. I have reason to suppose this may be the case between the Upper Devonian and the Carboniferous series. All veins, mineral or otherwise, come to the surface; and if the *Tubutellæ* be found therein, they will probably indicate the presence of freshwater conditions. The upper portions of those I have mentioned in this district represent the gossans of the lodes in more ancient rocks; and if, as at Yate and Tytherington, the *Tubutella* is caught up or surrounded by the mineral matter of the vein, there has either been a remodification of that portion of the vein, or it must have been contemporaneous with the organisms enclosed.

I have already shown that most of the mineral veins of the Mendips and South Wales are at least of Liassic age; and on this point I have much confidence in the belief that a careful examination of the gossans and other mineral constituents of the veins in our more ancient rocks will repay the labour, by giving either more precise indications of their age or of the physical conditions under which they were deposited.

Age of the Bristol Reptilia.—The varied points mentioned in this paper have drawn me away from the chief object which led to their consideration, viz. the age of the Bristol reptilia. As before remarked, the peculiar circumstances attending their discovery has always left this in some obscurity. They are now assigned by Mr. Etheridge to the Dolomitic Conglomerates at the base of the Keuper. These conglomerates are in great part composed of rounded boulders of the Carboniferous Limestone, some of them of great size, and seemingly requiring glacial conditions for their removal and transportation. Not only do they fringe the outcrops of the limestone from which they are derived, but they form an almost continuous deposit of considerable thickness, extending for many square miles in the Somersetshire coal-basin, the inclined ragged limestone edges of which are, in places, rendered by their denudation quite horizontal. The removal and redeposition of the conglomerates indicate very troublous times, during which it seems impossible for any organic life to have existed; for nothing could have withstood the grinding-processes to which it would have been subjected; and it is a significant fact that no organic remains have ever been referred to this period except the reptilians under notice.

For these reasons, and from my having found the teeth of *Thecodontosaurus* and *Palæosaurus* in the Rhætic deposit at Holwell, and also from my subsequent discovery of the Rhætic bone-bed and remains of that age almost alongside the Clifton reptilia, I had come to the conclusion that the latter belonged to this period—a view which further investigation respecting both Keuper and Rhætic reptilia requires me to modify. Seventeen Thecodont teeth, more or less perfect, are in my Holwell series. On comparison with those from Bristol, they are more robust, have a more wrinkled or striated surface, with the serrations on the edges smaller, less oblique, and more numerous. In my paper "On Abnormal Conditions" &c.*, I gave a section of variegated Keuper marls at Ruishton, near Taunton, one bed of which I described as a "Gritty conglomerate, with occasional sandy bands and intermediate layers of marl, with fish, reptile, and batrachian remains, fourteen inches thick." In this bed I have lately found some teeth of *Thecodontosaurus*, which appear in all respects identical, in form, structure, and the character of the serrations on their edges, with those from Bristol. It contains also *Acrodus keuperinus*, *Hybodus*, *Diplodus*, &c. It is rather a coarse sandy bed than a conglomerate; and, owing to its being rather unconsolidated, its remains are very fragile. There seems little doubt that this bed is on the horizon of that in Warwickshire which has yielded identical vertebrata; and if so, the Bristol reptilia will have to be removed one stage later in time, from the Dolomitic Conglomerate to the middle of the Upper Keuper.

It is an interesting palæontological fact that, although most of the generic forms of the Keuper recur in the Rhætic beds, so far as I have ascertained, the *species* differ, and are special to the two formations.

* Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 468.

Discussion.

The President spoke of the great industry and skill of the author in collecting the evidence on which this paper was based.

Mr. Tawney stated that Mr. Sanders held that the Dolomitic Conglomerate is of different ages in different parts of the district, and that the *Thecodontosaurus* is high up in the Keuper series. He thought that the fact of these remains being imbedded in solid conglomerate was scarcely reconcilable with the notion that they came from vein-infilling.

Dr. Duncan, with reference to the origin of the so-called *Tubutella*, stated that similar tubes might be seen in course of formation by the escape of air-bubbles from the surface of oysters and other shells covered with Algæ in turbid water containing carbonate of lime.

Prof. Seeley spoke of the great interest attaching to the question of the age of the *Thecodontosaurus*. He considered the specimens exhibited to belong to at least two genera. He stated that the ilium of *Thecodontosaurus* is Crocodilian, with Dinosaurian affinities.

Rev. H. H. Winwood supported the views of the author concerning the position of the veins of Durdham Down. He remarked upon the difficulty of understanding the mingling of different faunas in the same vein.

The President supported the views of Mr. W. Sanders, as expounded by Mr. Tawney, and bore testimony to the great value of Mr. Sanders's map of the Bristol area.

The Author agreed that the Magnesian Conglomerate is of different ages. He thought the Thecodontosaurian remains were obtained from the top of one of the veins. He stated that, while the veins occasionally contained the remains of fossils belonging to more than one geological period, others contained organisms which appeared special to a single period only, implying a denudation and refilling in veins, at the present time difficult to account for.

8. NOTES *on the* LOCALITY *of some* FOSSILS *found in the* CARBONIFEROUS ROCKS *at* T'ANG SHAN, CHINA. By JAMES W. CARRALL, Esq., F.G.S. &c., of H. I. M. Customs Service, China. (Read November 3, 1880.)

THE fossils which form the subject of this paper were found at T'ang Shan, Ch'iao Chia T'un, in Lan Chow of the Province of Chih Li, and about 120 miles from the treaty port of Tientsin, in a N.N.E. direction from that port.

A Chinese company has been formed, known as the "Chinese Engineering and Mining Company," to work the bituminous coal deposits there found on the European system.

Mining operations were commenced in 1878 by ascertaining the locality of the coal-seams by boring with the diamond boring-machine. The bore-holes, three in number, averaged about 400 feet apart; the third and deepest of the three driven reached a depth of 536 feet.

The seams dip at an angle of 45° to the north, calculated by the angle of the strata found in the bores.

The thickness of the coal-seams, not taken at the slant but parallel to the beds, is as follows:—

	ft.	in.	
No. 1 seam, N. of King seam	6	0	odd.
King seam	1	8	
No. 1 seam, S. of King seam	5	7	
No. 2 seam ,,	1	4	
No. 3 seam ,,	0	11	
No. 4 seam ,,	4	2	

The seams are in curves or folds; one seam that comes to the surface at the back of the colliery, again appears above ground halfway from the colliery to Kai P'ing (say three miles from the first outcrop), and again five miles further on, trending in a northerly direction.

Some very good magnetite, containing between 45 and 50 per cent. of metallic iron, has been found at Pai Mah Shan, about seventeen miles from T'ang Shan. It is intended to erect rolling-mills near the colliery, and place them also under foreign superintendence, trams being laid down (after permission has been obtained) between Pai Mah Shan and the hills for the transit of the ore.

The most striking feature of the geological formation of the country round T'ang Shan is, that above the Carboniferous system is first loose sand and then loam, the loam being uppermost, and extending but deepening all the way to Tientsin. Decomposed red sandstone was seen in the distance to the north.

A gradual ascent commences four miles before coming to Lu T'ai by land from Han Ku, and continues all the way to T'ang Shan. The colliery is situated in this incline, and is about a mile from the nearest hill, T'ang Shan, which I do not think is higher than 300 feet or thereabouts.

From the roundness of the hills and the way the chain is detached in places, there is not the least doubt in my mind that this part of the country was under water, and is now gradually rising, this also being proved by the fact that, according to Chinese history, the city of Tientsin was at one time situated on the seaside, and it is now some twenty-five miles inland.

NOTE *on the Specimens,* by W. CARRUTHERS, ESQ., F.R.S., F.G.S.

The specimens from China belong to a single species of *Annularia*; and I have no doubt that it is *A. longifolia*, Brongn., which is so abundant in our coal-measures in Britain, and is found on the continent and in North America. It occurs throughout the whole of the coal-bearing beds, from the lowest to the highest.

Newberry and others have described fossil plants from China associated with beds of coal; but these belong to Trias or still later formations. The great interest of this communication is that it records the existence of the true coal-measures in China, and gives a range to a well-known Carboniferous plant, in harmony with what we already know of other western contemporaneous Palæozoic plants.

DISCUSSION.

THE PRESIDENT remarked on the great interest attaching to the discovery of these Coal-measure fossils.

Mr. CARRUTHERS pointed out the interest attaching to the commencement of coal-mining in China. He remarked upon the worldwide distribution of certain Palæozoic species of plants.

PROF. JUDD spoke of the importance of this discovery in a country the geology of which was so little known.

Mr. BLANFORD suggested that possibly future observation might show that these plants were associated with Mesozoic forms. The Palæozoic flora had not a worldwide distribution. Mesozoic types of plants had been observed in Australia in Palæozoic beds.

PROF. SEELEY demurred to the conclusions of Mr. Carruthers as to the distribution of Palæozoic plants.

Mr. BLAKE supported Mr. Carruthers's views.

Mr. CARRUTHERS, in reply to Mr. Blanford, said he believed that the *Glossopteris*-beds of Australia are really Mesozoic and not Palæozoic in age.

Mr. BLANFORD said the late Rev. W. B. Clarke had found *Glossopteris*-beds intercalated amongst Palæozoic marine fossiliferous beds in coal-pits in New South Wales.

THE PRESIDENT supported the views of Mr. Carruthers and Mr. Blake, in opposition to those of Prof. Seeley.

PROF. JUDD supported Prof. Seeley's views as to the existence of life-provinces in Palæozoic times.

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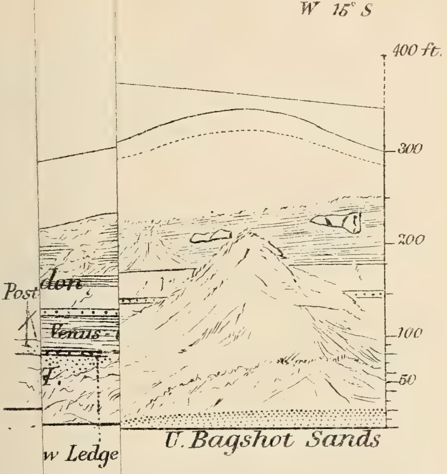

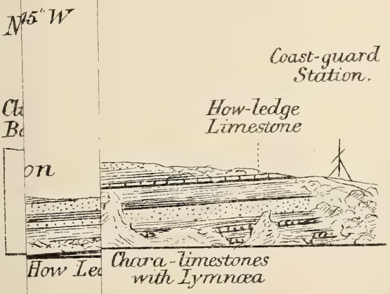

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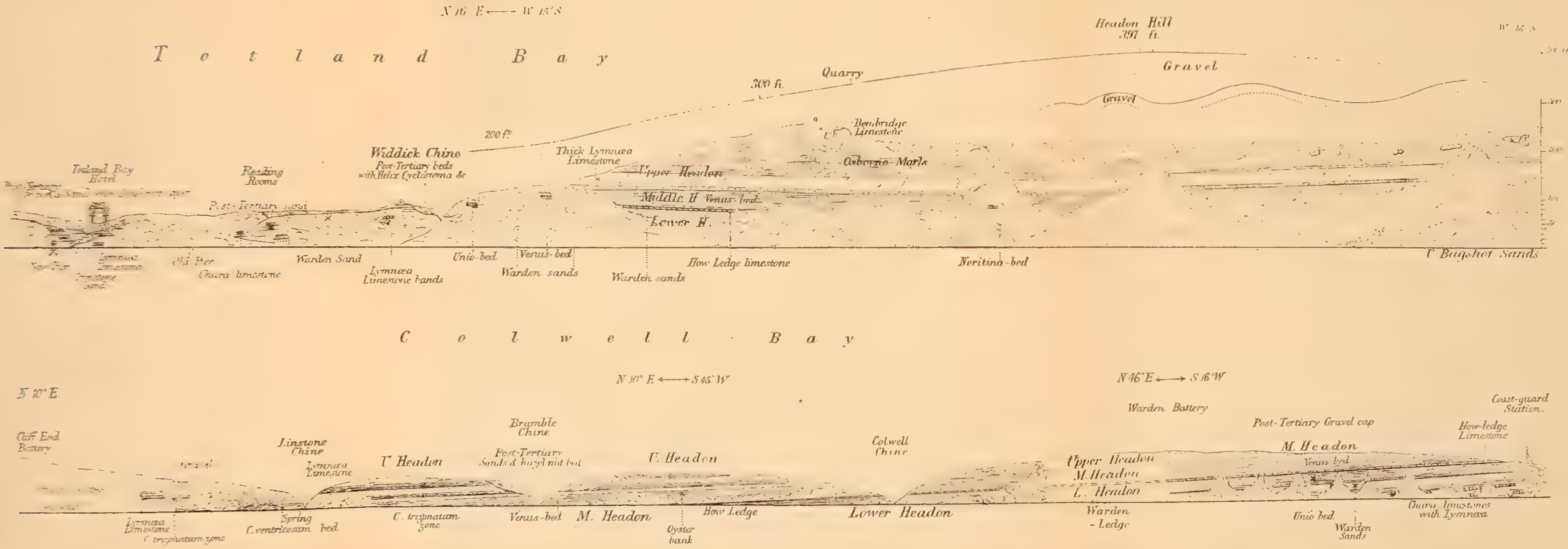
SECTION OF THE CLIFFS IN TOTLAND AND COLWELL BAYS, ISLE OF WIGHT.



Scale for Vertical Heights 1/2500. Scale for Horizontal Distances 1/5280, or 12 inches to the Mile (one inch to 146.6 yards.)

Fred^k Dangerfield Lith 22 Bedford S^t Covent Garden

9. *On the Beds at* Headon Hill *and* Colwell Bay *in the Isle of Wight.* By H. Keeping, Esq., and E. B. Tawney, Esq., M.A., F.G.S., of the Woodwardian Museum, Cambridge. (Read December 1, 1880.)

[Plate V.]

I. Introduction.

In a recent communication laid before the Society* the opinion was expressed that a serious error had been made by almost all previous writers in regarding the marine beds at Colwell Bay and Headon Hill as on the same geological horizon; we read:—"We shall now demonstrate that the Colwell-Bay marine beds are not, as has been hitherto supposed, the equivalent of those of Headon Hill and Hordwell Cliff, but that they occupy a distinct and much higher horizon." Upon the correction of this supposed error a new classification and nomenclature for the Upper Eocene formation of Britain was proposed.

The author further, after a review of the palæontological evidence, arrived at the conclusion that, on the one hand, the fossils in the Headon Hill and Hordwell Cliffs were identical, while, in the second place, those of Colwell Bay, White Cliff, and Brockenhurst presented the closest agreement among themselves. Then, comparing the former two localities, taken together, with the latter three, taken together, he considered (1) that the fauna of the first group was largely estuarine, and that of the second group marine; (2) that less than half the forms found in the former occur in the latter; (3) that the fauna of the former approximated more to that of the Barton beds, having about *one third* in common with them, while not more than *one fifth* of those from the latter three localities occur at Barton; (4) that the fauna of the former two agreed with that of a series of beds on the Continent which underlay and were older than beds containing the fauna of the last three.

In the following communication the authors attempt to traverse these points in the paper above referred to, in succession. By reference to detail-sections they argue that the stratigraphical evidence is plainly demonstrative of the identity of the Colwell-Bay and Headon-Hill marine series, the beds being continuous through the cliffs and easily traceable.

Referring to the palæontological evidence, it is shown from collections, made with their own hands this year, (1) that the fauna of the Colwell-Bay and Headon-Hill beds are identical; (2) that this fauna differs considerably from that of the Brockenhurst bed, which occupies a lower horizon; (3) that the Colwell-Bay bed has less than one third of its species common to Barton beds, while the Brockenhurst fauna has nearly one half in common with Barton beds.

* "On the Oligocene Strata of the Hampshire Basin," by Prof. J. W. Judd, F.R.S., Sec. G.S., Quart. Journ. Geol. Soc. vol. xxxvi. p. 137.

We conclude therefore that no reason has been shown for upsetting the classification of the strata adopted by the Geological Survey, and which, for nearly a quarter of a century, has been received among geologists.

Certainly we wish to uphold in its integrity the work of the late E. Forbes *, and the classification of beds adopted by him when Palæontologist to the Geological Survey, and subsequently confirmed by Mr. H. W. Bristow, F.R.S., in the second Survey Memoir † on the Isle of Wight.

One of the authors, from his long residence in the district and his constant occupation with these beds, has been long satisfied that E. Forbes's account of the beds is true to nature, and his classification fully borne out by lithological identity of beds, as well as by distribution of the fossils. The present notes, then, are based on his part upon an aquaintance with the district, and the work of the Geological Survey there during its progress, supplemented by subsequent visits, and specially this summer by a joint examination by both, including measurement of beds and collection of fossils, which, however incomplete, was made bed by bed, and represents the prevailing fauna of each—a point on which we lay great stress.

We do not wish to delay over the history of previous opinion, which has been sufficiently treated in Forbes's and Prof. Judd's memoirs ; but the latest criticism of Forbes's work (*op. cit.* p. 141) may be alluded to.

II. Totland and Colwell Bays.

The Survey Horizontal Section east of Headon Hill.—The first point at issue between Forbes supported by " nearly all observers, " on the one hand, and Prof. Judd on the other, is whether certain marine beds known as the Middle Headon (including the "Venus-bed" of local collectors) in Colwell Bay are rightly associated with similar marine beds in Headon Hill. The Survey identify them, and correlate the freshwater beds immediately above and below as Upper and Lower Headon respectively in both localities. This succession, however, is stigmatized (*op. cit.* p. 142) as a " mistake " of which the " primary cause " is considered to be an " assumed " existence " of a great anticlinal fold of which the summit is supposed to be seen in Totland Bay. The manner in which this supposed anticlinal is regarded as having affected the strata is illustrated in Prof. E. Forbes's memoir, pl. vii. fig. 1, and also in Sheet 47 of the Horizontal Sections published by the Geological Survey. And yet further on we read (*op. cit.* p. 146), " at Totland Bay there is undoubted evidence of the presence of a slight anticlinal fold having its summit near Widdick Chine, to the westward of which the beds for a short distance have a slight dip to the south ;" so that after all the only mistake the Survey could have made would have been to exaggerate the dip.

We are next told of the E. and W. flexure, which causes a slight

* On the Tertiary Fluvio-marine Formation of the Isle of Wight, by Prof. E. Forbes, F.R.S., 1856 [Memoirs of the Geological Survey of Great Britain].

† The Geology of the Isle of Wight, by H. W. Bristow [Sheet 10], 1862.

dip to the W. in Headon Hill; and it is implied that the Survey section is false, owing to the neglect of this consideration. We must point out, however, that this Section, Sheet 47, fig. 2, in which alone the anticlinal is shown, does not go through the summit of Headon Hill at all, and passes about a half mile inland at the latitude of Widdick Chine: in it the Upper Bagshot beds are made to appear a little above the sea-level at that spot; and we have great confidence that the calculations on which this is grounded are correct *; they would be brought up by the anticlinal of which the existence has just been acknowledged. So far then, we may observe, no reason has been shown why the Survey Section should not be received as correct.

Prof. Judd's Section (*op. cit.* pl. vii.).—We do not find any indications of the direction in which this section is drawn; but, from the names of chines which occur in it, we presume that it is intended to start from Alum Bay in a N.E. direction through Headon Hill, and after that to follow the coast-line; in this case it is not precisely comparable with the Survey Section, whose direction is indicated on the map as passing inland and crossing from sea to Solent. It will be seen at once why it does not correspond to nature, and agree with the views of other observers. It will be noticed that the Marine bed of the Headon Group (β of fig. 3, pl. vii.) is made to exist at the sea-level near Widdick Chine; and in the letterpress we read (*op. cit.* p. 147) "it is admitted on all hands that at the north-east angle of Headon Hill the marine band [Middle Headon beds] makes its appearence just above the sea-level." *On the contrary, we cannot imagine any one putting the bed in this position.* At the spot indicated the top of the Middle Headon is about 105 feet above the sea-level; so that the section, in our opinion, is erroneous: the dip thereby is exaggerated; and 105 feet of beds are intercalated which do not exist. We shall prove this presently by a detail-section at this point of the hill; at the present moment we wish to point out that, with the correction of this error of 105 feet, the argument against the accuracy of the Survey section entirely breaks down.

Thus, we are told that the height of the Bembridge Limestone above the sea-level at this point is 250 feet (*op. cit.* p. 147); then, the marine band being put at the sea-level, it follows that 250 feet of strata must intervene between that and the Bembridge Limestone; "but the Geological Survey [vertical] section shows less than one half of that thickness of beds, and in Colwell Bay the distance between the Bembridge Limestone and the marine band is 120 feet †. . . . . But 250 feet of strata is precisely the thickness required by my interpretation." Since we have to subtract 105 feet from

* The greater thickness of Upper Bagshot beds above the sea-level in the same line of section in the old edition of Sheet 47, and in the Plates of the Memoirs, seems due to the outline of the ground at the S. end being raised too high above Ordnance datum; probably the accurate height of the Beacon Hill was not obtainable till 1870, when the revised edition of Sheet 47 was published; otherwise the sections are practically identical.

† It would be 133 feet, according to Mr. Bristow's estimate (Forbes's Mem. p. 142), to the top of the Bembridge Limestone in Colwell Bay.

the estimate in the paper above referred to, we shall certainly have to abandon this section in favour of that of the Survey; for the thickness left, viz. 145 feet, more nearly corresponds with the thickness of the Bembridge, Upper Headon, and Osborne beds, which are stated by the Survey to exist at this spot, and whose thickness would be 144 feet *.

It would appear, therefore, that there is no necessity for supposing "that, in a distance of little more than one mile, a mass of beds 120 feet thick has expanded to 250 feet, and, further, that the beds have been entirely changed in their mineral character."

We do not understand the warning (*op. cit.* p. 146) against "trusting to the general impression which is produced by viewing these beds from a distance," nor the purport of the following statement:—"The strata of How Ledge and Warden Point are seen in such a true-scale section to be clearly continued in precisely similar beds appearing underneath the gravel of Headon Hill." The section offered to us is on rather too small a scale to show detail; but, in our opinion, the beds are inaccurately laid down in Warden Cliff, and no such bed as the Brockenhurst bed occurs at all in Headon Hill.

Before we commenced drawing our section, we traced the beds along the cliffs, measured their thickness, and obtained their height above the sea-level at various points, but found it possible only to show general results in the horizontal section; the details are embodied in the vertical sections.

Vertical Section at North-east Corner of Headon Hill (fig. 1, p. 91).—We may now proceed to a more detailed account of the beds. We will begin near the N.E. corner, where the Bembridge Limestone is seen, indicated on the section (*op. cit.* pl. vii. fig. 2) with an asterisk, and lettered 250 feet altitude. (The quarry there is not now at work; but it is the place at which one of us has obtained most of the finest specimens of *Palæotherium* which have been found in the Isle of Wight.) We take the thickness from the Survey Memoir as 25 feet.

Beneath this, in the section (fig. 3, pl. vii.), we notice a blank space with the legend "slopes covered by gravel and landslips." We think this scarcely a correct description. Landslips exist in that the clays and marls tumble and form taluses; but we saw no gravel covering the slopes between the Bembridge Limestone and Widdick Chine; nor indeed does it entirely conceal the beds between the Bembridge and Upper Headon Limestones all the way to Heatherwood Point in the other direction; at intervals tumbled gravel conceals a limited portion of them.

The gravel west of Widdick Chine is not accurately depicted: the thickness is exaggerated, while its horizontal extent is overestimated here †. It does not appear in the cliff certainly beyond 80 yards

* Taking the Bembridge Limestone at 25 feet, the Upper Headon and Osborne at 119 feet, as read off their vertical section by scale, after altering their lower boundary a few feet to correspond with our own.

† Mr. Bristow (Forbes's Mem. p. 105) gives the entire horizontal extension of the Lacustrine beds (Post-Tertiary) on both sides of the chine as 350 yards; the section under review makes the gravel extend about 720 yards.

from the chine on the west side (private grounds interfere with examination nearer the chine).

We should say, from our examination of the ground which intervenes between the escarpment of the thick Upper Headon Limestone and the Bembridge, that there is no difficulty in seeing what beds exist there. It is true they are sufficiently interrupted by local taluses to cause trouble in making a continuous measurement; but the tumbled portions are partial and affect only a few feet of beds at a time, so that by moving the observer's position laterally it is possible to see all the beds in turn. This we claim to have done; we do not pretend that our measurement of the beds is any thing but rough, though controlled by repetition, because we had no levelling-instruments with us, and in shifting horizontally from one spot to another there might be frequently a slight error in picking up the next bed to be measured. We might describe the beds immediately below the Bembridge Limestone, in descending order, as follows:—yellowish and ochry marls, red and grey mottled marls, marly clays with nodular bands, greenish-grey clays, pale greyish clays, grey and ochry clays, stiff pale or whitish clays with calcareous lenticular bands, red and green mottled marls, "cherry marl" with calcareous bands. These are the *Osborne beds* of the Survey; and they come in the precise position assigned to them in the Survey Memoirs. They are well characterized by the "cherry marl"—the mottled red and pale greenish marl which distinguishes the group from the Upper Headon; and we consider the subdivision a very useful one in the classification of beds. Their thickness here, by our comparatively rough way of measurement, is 70 feet. The vertical section of the Survey Sheet 25 gives 71 feet, reading off by scale down to the bed which we have taken as our boundary; their measurement seems to have been taken near Heatherwood Point, where this series contains a thick limestone of 18 feet; as noticed by previous observers, this limestone thins out to the east, and is only represented by nodular calcareous bands at the east end of the hill; its loss will probably be compensated by an increase in the clays. Our results are perhaps sufficiently near to those of the Survey to prove that the same series of beds has been examined in both cases. We should remark that from the lower red beds it is perfectly easy to draw a continuous vertical section to the beds below; and from here our measurements to the Lower Headon are uninterrupted in a vertical line. The Osborne beds yield few interesting fossils; *Limnæa* is abundant in the calcareous bands; but, as noticed by Forbes (Mem. p. 81), the shell-substance is not preserved. These beds are identical lithologically with the mottled red and pale green series at Cliff End.

The beds next below the red series are grey and ochry clays, very rich in *Potamomya gregaria* and *Paludina lenta* beautifully preserved: we place these in the Upper Headon; they are about 15 feet thick *.

* In the Survey Section no. 5, at Headon Hill (sheet 25, Vert. Sect.), these clays are included in the Osborne series; but in the Vert. Section. no. 4, at Colwell Bay, the boundary is so drawn that analogous clays are put into the Upper Headon.

This brings us to the vertical escarpment of the thick limestones, so conspicuous a band along Headon Hill cliffs that it is indicated on the Ordnance maps, both on the 25-inch and the 6-inch. We pause awhile to draw attention to the fact that we have accounted for about 110 feet of beds from the top of the Bembridge to the top of the great limestone (Upper Headon); and the Brockenhurst series does not exist here. *There is not a single marine fossil to be found in that interval; nor is there any bed with the faintest resemblance either lithologically or palæontologically to the Colwell-Bay* Venus-*bed.* This is in opposition to the view (*l. c.* p. 176 *et passim*) that the Colwell-Bay series exists here "entirely concealed" by some supposed gravel talus*; yet it is upon the existence of such a second marine series, thus supposed to be added above the Venus-bed that the presence of a Brockenhurst series at the west end of the island is inferred.

Next we turn to consider the thick limestone of the escarpment, the Limnæa-limestone of the Upper Headon. It is in several beds, of which details are given by the Survey; we measured it by suspending a tape, and found it 27 feet (fig. 1, p. 91).

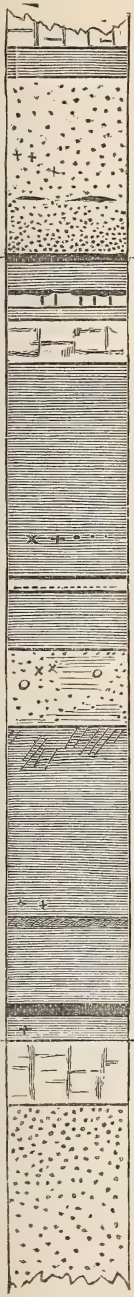
The only difficulty in correlating the Headon-Hill beds with those of Colwell Bay is centred in this limestone: it might be a difficulty to those who would have expected *a priori* that the limestone would have maintained its thickness in direction of dip for a mile or two to the north; for we identify it with a limestone at Cliff End not above 1 foot 8 inches thick. It would be equally a difficulty according to the correlation which identifies it with the How-Ledge limestone (*op. cit.* p. 144); in this case the 27 feet has thinned to 3 feet at How Ledge, a distance of $1\frac{1}{6}$ mile in a straight line, while in Warden Cliff (only 926 yards distant from the Headon-Hill bed) it is about 5 feet; so that it must have thinned very rapidly at the first stage. The limestone in the Upper Headon at Cliff End, with which we identify it, is distant 1 mile 926 yards. In either case it thins out considerably to the north, as noticed by E. Forbes (Mem. p. 84). We shall be able to prove that it does not occupy the same position as the How-Ledge bed; for we have recognized that bed, which forms the summit of the Lower Headon, at a lower position in Headon Hill and in its natural position, viz. below the marine series (Middle Headon), as in Warden Cliff, where it was last seen. As a palæontological distinction between the Upper Headon limestone of Headon Hill and Cliff End † and the Lower Headon limestone

* With respect to the "inextricable difficulties and confusion" (*l. c.* p. 144) in which the Survey is supposed to be involved by their not allowing the Colwell Marine bed to come where the Osborne beds are placed, and which is supposed to be shown by 48 feet of strata being classified in the letterpress (Forbes's Mem. p. 81) as Osborne, while in the plate they are classed as Upper Headon, this is merely a question of classification and the drawing of a boundary-line, matters entirely subjective and not affecting the total thickness; their vertical section shows almost the same thickness of beds consistently, notwithstanding certain irregularities in the boundaries and classification.

† In the legend to the Survey Vertical Section, sheet 25, no. 4, this limestone in the Upper Headon is said to form How Ledge; this is plainly an oversight or clerical error, as is also the statement in Forbes's Memoir, p. 132, that the How-Ledge bed is faulted in Warden Cliff. The fourteen faults mentioned affect the Upper Headon limestone at Cliff End: their section is fairly correct; but there seems to have been some confusion between Warden Point and Cliff-End Point in the letterpress.

Fig. 1.—*Vertical Section of Beds at the North-east corner of Headon Hill.*
(Scale, 8 feet to the inch.)

Bembridge Limestone ...... 25 feet.
Osborne beds..................... 70 „
Upper Headon .... 49 „ (total).



Upper Headon.

Part of thick *Limnæa*-limestone. *Limnæa fusiformis*, &c.

ft. in. 1 0 — Laminated greenish clay, with broken *Paludina*.

6½–8 0 — Whity-brown to buff sands, with layers of lignitic matter.

Greyer sands below. *Potamomya, Melania muricata, Unio, Paludina lenta.*

0 3 — Lignite.

Middle Headon.

9 in.–2 ft. — Greyish-green clays. *C. ventricosum*-bed with .... *Vicarya concava, Marginella vittata, Neritina concava, Melania muricata*, &c.

6 in. — ...*Limnæa*-limestone, soft and crumbling, with a thin lignite at top.

6 in. — ...Verdigris-green clay, with rootlets.

ft. in. 1 10 — *Limnæa*-limestone.

9 2 — Stiff green clays with conchoidal fracture in drying.

Oyster-bed towards the base.

Clay becoming greyer below. Fossils .... *Fusus labiatus, Mel. fasciata, M. muricata, Nerita aperta, Cer. variabile, C. pseudocinctum, Ostrea velata, Mytilus affinis, Corbicula obovata, Lucina colvellensis.*

3 0 — Alternating grey and ochry clays.

3 0 — "*Venus*-bed," richest portion, contains scattered flints, brown sandy clay becoming green clay and sand below. Fossils........................... *Cyth. incrassata, Mactra fastigiata, Mya angustata, Corbicula obovata, Nucula lissa, N. headonensis, Trig. deltoidea, Fusus labiatus, Cancell. elongata, Melanopsis fusiformis, Voluta spinosa, Vic. concava, Natica Studeri.*

Thin grey sandy clays, weathering brown.

8 0 — *Cytherea incrassata* &c. scattered throughout.

Mya angustata, especially near base.

Chocolate-brown or blackish sands. *Trig. deltoidea, Cer. pseudocinctum, Natica labellata, Melan. fusiformis.*

2 6 — *Trigonocœlia*-bed.

0 6 — Blackish-brown sands, *Neritina*-bed: *N. concava, M. fusiformis, C. obovata.*

1–1 3 — Very stiff tenacious clay.

Lower Headon.

2½–4 6 — *Limnæa*-limestone, "How-Ledge limestone:" *L. longiscata, fusiformis*, &c.

8 6 seen. — Whity-brown or yellow sands and sand-rock, with layers of *Paludina* and *Potamomya.*

[The base concealed by tumble and undercliff.]

of How Ledge, we may adduce that the former is very rich in *Planorbis*, while in the latter these shells are comparatively rare, the fossils being chiefly *Limnæa*.

As the Upper Headon limestone is the strongest bed in the section and forms an escarpment through the greater part of Headon Hill, in it we may obtain a datum line. We take as a point of reference the spot where the top of the escarpment cuts the surface of the ground or outline of the cliff; this is seen on the 6-inch or 25-inch map to be about halfway between the 100 feet and 200 feet contour-lines. From these points of known altitude, by the aid of the barometer, we obtain the height of our point of reference: it is about 140 feet above Ordnance datum.

The beds below the Limnæa-limestone are green clay, 1 foot, with broken *Paludina*, then pale buff or whitish sands, varying from 6½ to 8 feet, with occasional layers of lignitic matter, *Potamomya*, and *Melania muricata*; below, where it is sometimes grey, *Unio Solandri* and *Paludina lenta* may occur. We take this bed with the 3-inch lignite below as the base of the Upper Headon. The boundary chosen is, of course, arbitrary; but the fact of the next bed being decidedly brackish inclines us to draw the division from the Middle Headon here; the Survey vertical section, sheet 25, places it a few feet lower.

Our estimate for the Upper Headon at Headon Hill amounts to a thickness of 50 feet; the thickness on the Survey vertical section is given as 37 feet; but if we read off the distance between the beds which we have taken as boundaries, it becomes 48 feet. The combined thickness of Osborne and Upper Headon beds, according to the Survey section, is 119 feet, *i.e.* adopting the top of the *C. ventricosum* bed as the boundary; our estimate, taken at the north-east end of the hill, is 120 feet. The agreement is sufficiently close to render it probable that a thickness above the average of the calcareous portion is accompanied at the same spot by a diminution in the clays; so that the balance of average thickness is maintained at both ends of the hill. As we have said, we think it convenient to retain the name "Osborne Series" for the red and greenish mottled clays and marls and pale greenish-white limestones, since these physical characters distinguish them at once along this side of the Solent. We must decline to accept the statement (*op. cit.* p. 169) that "under this name beds lying below the Brockenhurst series, as at Headon Hill, have been confounded with others on a totally different horizon, above the Brockenhurst series."

We next come to the *Middle Headon*. E. Forbes relates (Mem. p. 85) that the uppermost and lower portions at Headon Hill are brackish-water beds abounding in *Cerithium ventricosum*, *C. pseudocinctum*, *C. concavum*, *Neritina concava*, and *Nematuræ*, the conditions being less purely marine than at Colwell Bay. This is, no doubt, true of the series as a whole; for below the *C. ventricosum* bed there are two freshwater Limnæa-limestones. But it appears to us that too much has been made of this; for instance, the lower Neritina-bed is identical in Headon Hill with the similar bed at Warden

Cliff, and again in Colwell Bay, both physically and as to its fossils; when we come to the portion of the series richest in *Cytherea incrassata* known as the "Venus-bed" proper, we find identically the same fossils as in Colwell Bay; we cannot detect any difference, so far as our researches go.

The uppermost bed is dark greenish clay, varying from 9 inches to 2 feet in thickness. When at its thickest the sands above are proportionally thinner. It is extraordinarily rich in fossils for the depth of one foot, chiefly *Neritina concava*, *Cerithium* (*Vicarya*) *concavum*, *C. ventricosum*, *Corbicula obovata*, *Marginella vittata*, *Melania muricata*, *Melanopsis fusiformis*. We may call it the *C. ventricosum* bed; for this fossil seems almost confined to this horizon, while the *Vicarya concava* is found here all through the Middle Headon, though especially plentiful in this bed; its underside is occupied by an impure lignite band, with freshwater shells (*Limnœa* and *Planorbis*), and rootlets, lying on a thin crumbly buff Limnæa-limestone. Both together are 4 to 6 inches. Below is verdigris-green clay, 6 inches; next a buff freshwater limestone with *Limnœa*, 1 foot 8 inches to 2 feet, the shells frequently blackish in colour. These beds betoken certainly a recurrence of freshwater conditions after the brackish bed above. Next follow truly marine beds—first stiff green and grey clay, about 9 feet, with a conchoidal fracture when dry. The abundance of oysters, *O. velata* (Wood), is the chief fossil feature; these and the other fossils occur mostly towards the base. Such fossils are *Fusus* (*Pisania*) *labiatus*, *Nerita aperta*, *Melania fasciata*, *M. muricata*, *Cerithium variabile*, *C. pseudocinctum*, *Mytilus affinis*, *Corbicula obovata*.

The fossils cited are merely the most common, such as may be found in a few minutes' search; but these being the most characteristic, seem to us precisely those required for the identification and correlation of beds.

Comparing the beds noticed so far with those at Colwell Bay, we observe practically identity of fossils; this last, which we may call the oyster-bed, is identical with the oyster-bed of Colwell Bay; in both localities *C. ventricosum* occurs above this bed, and there only, so far as we know.

Next below follow alternations of grey and ochry silts, 3 feet, in which we observed no fossils. Below are 11 feet of beds, brown sandy clay above becoming green clayey sands below, and then grey sandy clays: this is the "Venus-bed" of *collectors*; *Cytherea incrassata* occurs near the top and is scattered throughout the whole bed, but is most abundant for the space of one foot. The fossils obtained from the Venus-bed in a few minutes' search were *Cytherea incrassata*, *Mya angustata*, *Mactra fastigiata*, *Psammobia rudis*, *P. æstuarina* (Ed. MS.), *Nucula headonensis*, *N. nudata*, *Trigonocœlia deltoidea*, *Corbicula obovata*, *Vicarya concava*, *Ancillaria buccinoides*, *Fusus labiatus*, *Cancellaria elongata*, *Natica Studeri*, *N. labellata*, *Voluta spinosa*, *Melanopsis fusiformis*, *Nematura parvula*, *Limnœa longiscata*, *Planorbis obtusus*, crab-claw (*Callianassa*), coprolite.

Towards the base *Mya angustata* and *Corbicula obovata* were particularly abundant.

Next below the *Venus*-bed is the *Trigonocœlia*-bed, chocolate-brown sands, 3½ feet, with sometimes a blackish tint; we so call the bed from the principal fossil which occurs at precisely the same horizon in Warden Cliff and Colwell Bay; other fossils are *Cerithium pseudocinctum*, *Melanopsis fusiformis*, *Natica labellata*. Below are blackish-brown sands, 6 inches; at base is enough carbonaceous matter almost to amount to a lignite band; this may be called the *Neritina*-bed, the chief fossils are *Neritina concava*, *Melanopsis fusiformis*, *Corbicula obovata*, the latter in perfect condition, very large, and showing concentric colour-bands. The *Neritina*-bed occurs in the same position towards the base of the series in Warden Cliff and Colwell Bay. This can only be explained by admitting that the marine series in Totland Bay and Colwell Bay are identical; the *Ventricosum* bed at the top, and the *Neritina* and *Trigonocœlia* beds at the base, identical in physical and fossil characters, are strong presumptive proof of this.

Below is very stiff dark-grey clay, 1 foot to 1 foot 3 inches; fossils occur in patches, *Neritina concava*, *Cerithium pseudocinctum*, *Melania muricata*, *Limnœa*, *Corbicula obovata*. This is the lowest bed of the Middle Headon here. Summing up, we obtain a thickness of from 31 feet 9 inches to 33 feet for the Middle Headon of Headon Hill at the N.E. end. Reading off the Survey vertical section by scale, we obtain 35 feet for it between the boundaries adopted by us * for the thickness towards the west end.

The height of the base of the Middle Headon above the sea at this point, viz. about 120 yards in horizontal distance west of our reference-point, is by subtraction 72 feet. Direct barometric observations gave about 70 feet. We have already used these figures when alluding to the position assigned to this series.

The first bed of the *Lower Headon* is a Limnæa-limestone of the usual buff colour: it is 2 feet thick at this point; but a little further west we obtained a measure of 4 feet. This is in our opinion the well-known bed which forms *the top of the Lower Headon* in *Warden Cliff*, where it is quite a marked feature. It has there and in Colwell Bay precisely the same position in the series, supporting the Middle Headon—recognized by the *Neritina*-bed with all its characteristic features, the *Trigonocœlia*-bed, and so on. From Warden Cliff it is traceable uninterruptedly to How Ledge, where it disappears beneath the sea-level; we therefore speak of it as the "How-Ledge limestone." It is correctly drawn on the Survey vertical sections, sheet 25, nos. 4 and 5, where in the legend is a clerical error, to which we have already alluded. This bed is so distinctly lacustrine,

* Some irregularity in the boundaries of the Survey vertical section is to be noticed: viz. in the Headon-Hill Section, no. 5, the boundary is placed below the How-Ledge Limestone; in the Colwell-Bay section, no. 4, the boundary is placed at one bed above the How-Ledge Limestone; this seems an error of the engraver, and of course does not affect the thickness of the beds.

being almost made up of *Limnæa* shells and their débris, that it seems most convenient to include it in the Lower freshwater group; and it makes an especially good boundary.

The beds which follow next below the Limnæa-limestone at this spot are whity-brown or yellowish sands, and sand rock with *Paludina* and *Potamomya* in layers; 8½ feet are seen; this is all that is exposed of the Lower Headon here. At this spot all the ground below is tumble or undercliff; and for a more complete section of the Lower Headon in the present state of the cliffs we shall do best to take the one exposed in Warden Cliff and under Totland Bay Hotel, where the fresh road-cuttings to the New Pier have been of service to us.

We consider that we have already sufficiently proved the identity of this lower limestone in Headon Hill with the How-Ledge bed of Warden Cliff; but if any objection be raised that its relations to certain specified bands in the (Middle Headon) Marine series being found identical in both localities is not conclusive—even though it has been shown that no other marine bed exists in Headon Hill—we have further means at our command. There are, however, only two beds in Headon Hill with which the How-Ledge bed could be continuous: viz. either it is the same as the thick Upper Headon limestone (which we consider impossible, as the beds both above and below would then just be reversed, viz. freshwater above and marine below, instead of *vice versâ*), or it must be identical with the one to which we assign it. It is possible, however, to settle the point by ocular demonstration *. Though the How-Ledge limestone is denuded from the top of the curve between Weston and Widdick Chines, some of the lower beds are traceable the whole way. Accordingly we can join on the section in Headon Hill to that in Warden Cliff. We account thus for a continuous section of beds from the lowest seen beds of the Lower Headon, through the Middle and Upper Headon of Colwell Bay, to the Bembridge Limestone on the north, and again from the same base of the Lower Headon, through the succeeding Lower Headon beds in the cliffs between Weston and Widdick Chines, to the sand below the How-Ledge limestone at the N.E. corner of Headon Hill, and thence up to the Bembridge limestone on the south; and we find that the section is identical in both cases. There is only one Marine (Middle Headon) series, lying between two freshwater series, the Lower and Upper Headon.

Of course, all this has been done before by the Geological Survey, and our work is nothing but a confirmation of results already sufficiently established by E. Forbes and Mr. Bristow.

On our horizontal section of the coast we have endeavoured to represent the position of the beds in the cliffs and the extent to which

* We are indebted to the Rev. O. Fisher, F.G.S., who specially visited Totland Bay this autumn, for the information that the Venus-bed is found in the Totland-Bay brickyard some little way above and behind the top of the cliff between the chines. He points out that since this is the only part where it is missing from the cliff, it is the link needed to prove that the bed is continuous all through.

they are traceable; but though the vertical scale is more than twice the horizontal, it is not possible to show the details; for these we must refer to the vertical sections.

Lower Headon Beds of the cliffs between Weston and Widdick Chines.—We left off with the Potamomya-sands, $8\frac{1}{2}$ feet below the How-Ledge limestone; these are easily traceable through the grass-slopes, exposures of a few feet occurring at intervals all the way to Widdick Chine, about 230 yards distant. There good sections are seen on each side of the roadway; here the sands have in the upper part more clay mixed with them, as in Warden Cliff. Whiter sands are below; above are alternating whity-brown sands with bluish silts. *Melania turritissima* occurs in the latter, a shell which occurs, indeed, in the Bembridge Marls at Hamstead, but which, in this district, we only know at one horizon, viz. the *Unio Solandri* bed, and one above that, at Warden Cliff and Colwell Bay; we remark its analogous position at Widdick Chine. Below the sands, again, is pale greenish clay, 3 inches; in descending order, soft buff Limnæa-limestone, 1 foot; brownish sands with *Potamomya* and reptile dermal ossifications: these occupy the position of the Crocodile-beds in the Lower Headon at Hordwell; they continue along the cliff as we walk northwards. Below is a carbonaceous band or impure lignite, 6 inches, then a repetition of clays with carbonaceous layers, followed by another Limnæa-limestone, 10 inches, Potamomya-clays, 4 feet, another Limnæa-limestone, 1 foot, greenish clays with *Paludina lenta*, *Potamomya plana*, *Melanopsis brevis*, *Limnæa* &c.; another Limnæa-limestone, 8 inches, full of *Gyrogonites*, below that clay with carbonaceous layers passing to drab sands, about 2 feet; then a lignite layer and impure Limnæa-limestone, soft and crumbling at the outcrop. The limestone full of *Gyrogonites* is noteworthy, as it occurs only low down in the Lower Headon, and serves to mark our position in the series at this spot. Now this Chara-limestone is exposed again at the back of the Reading Rooms, where there are the same five limestones seen as near Widdick Chine, the Chara-bed being the lowest but one; this is well seen behind the Reading Rooms, where there has been a cutting through the Lower Headon beds for a new pathway. It will be noticed that we have passed five thin Limnæa-limestones in the lower part of the Lower Headon in the cliffs immediately north of Widdick Chine, and again behind the Reading Rooms; we see them again as they rise from beneath the sea-level beyond the new pier under Warden Cliff; they are seen also in the recent scarping under Totland Bay Hotel. The continuity, then, of the section from the five lower limestones under Warden Cliff through Weston Chine to Widdick Chine is undoubted; and from there we continue through the sands above to the How-Ledge limestone in Headon Hill. The beds in the cliff here belong entirely to the Lower Headon*.

* The top of the cliff at the back of the Reading Rooms has a capping of about 7 feet of Post-tertiary sand; at the base of this is a layer of flints and derived marine fossils, *Cytherea incrassata*, *Ostrea velata*, &c., showing that the marine Middle Headon series existed here above this level. This Post-tertiary sand lies on the (Lower Headon) Warden sands.

Lower Headon of Warden Cliff.—The lowest beds seen are below the Totland Bay Hotel at Weston Chine. We therefore start from here in making a measure of the Lower Headon series, meeting higher beds as we go north towards Warden Point. The details of this measurement are given in the vertical section, fig. 2 (p. 98); we need here allude to only a few of the beds. The lowest bed seen in Totland Bay is a few yards south of the Coast-guard boathouse; here are visible, in ascending order, whity-brown sands, 1½ foot, a hard purple sandy ironstone, 6 inches, greenish clay, 4 feet.

In our vertical section, fig. 2, we have drawn an interruption in these clays, because we are not absolutely sure that they are identical with the similar clay in the road-cutting at the pier-head on the other side of the boathouse; there is little doubt of it, however. At the pier-head are seen 3 feet of clay in the road-cutting (after our section was drawn, on a later visit, a drain-opening showed 4¼ feet); and from this point the section is continuous without interruption. There is therefore only a possibility of error of a few feet.

Five thin Limnæa-limestones will be noticed. The two lowest contain *Chara*-seeds at the pier-head; on following them to their outcrop along the shore it is found that the fourth of them also has *Chara*-seeds at that point; the fifth, 1 foot 3 inches thick, is 50 feet below the top of the How-Ledge limestone, or top of the Lower Headon.

From the top of the cliffs these limestones may be seen at low water, forming five submarine ledges parallel to the great ledge at Warden Point; they strike N. 36° W.

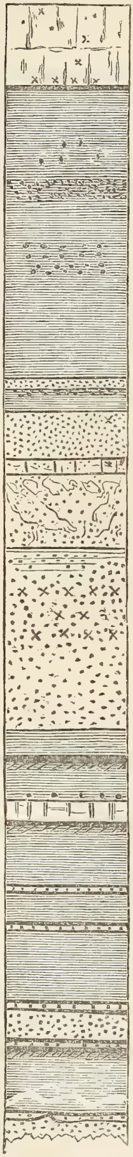
As there is great uniformity in these freshwater beds, and their fossils mostly occur in the Upper Headon also, we pass over many beds to notice the sand-rock bed, which is a conspicuous feature in Warden Cliff. This sandstone, somewhat calcareous at places and friable at others, forms Warden Ledge, and runs out at the top of the cliff close below the flagstaff of the coast-guard station.

About 11 feet above that comes the *Unio Solandri* bed* with *Melania turritissima*, a bed of which we have already noted a portion in the cliff at Widdick Chine; the *M. turritissima* occurs through a greater thickness of the 11½ feet of clays than does the *Unio*. Next comes the How-Ledge limestone, 5 feet, in two beds containing *Limnœa fusiformis*, with a carbonaceous or lignitic band at the base. The shells are more crowded at the base; and the lower surface of the blocks fallen from the cliff is a sight pleasing to the collector of fossils. The dip of this bed in Warden Cliff, calculated from its horizontal extension on the 25-inch map, between its position at How Ledge at sea-level and a point of known elevation near the flag-staff, is a slope of about 1 in 45. This How-Ledge bed crops out at the top of the cliff, a little north of the coast-guard flagstaff; it is

* The Unio-bed with *Melania turritissima* occupies an analogous position at Hordwell Cliff, being at about the same distance below the Lymnæa-limestone (which is a diminutive representative of the How-Ledge bed), where it has precisely the same lithological characters with the same abundance of black seeds (*Carpolithes*) as at Colwell Bay and Warden Cliff; it crops out again with the same fossils on the shore immediately south of Milford.

Fig. 2.—*Vertical Section of Lower-Headon (freshwater) Beds exposed between Weston Chine and Warden Cliff.*

(Scale, 12 feet to the inch.)



LOWER HEADON.

ft.	in.	
		Limnæa-limestone, in two beds, buff colour.
5	0	How-Ledge bed; extends from How Ledge to Coast-guard Station.—*L. fusiformis.*
		Lignitic or carbonaceous band.
		Pale grey clays, rather mottled. *Paludina* at intervals.
5	0	
		Alternating greenish and greyer clays, rather sandy below, but more so above. *Melania turritissima* and other fossils in layers at intervals.
6	6	
		Unio-bed.
		Laminated grey sandy clay, with *Unio Solandri, Mel. turritissima.*
6	0	Stiff clays, grey or brown in places,
2	0	Sandy grey clay, more sandy above, with *Paludina lenta, Melanopsis brevis, Potamomya plana, Unio Solandri.*
2	9	Pale whity-brown crumbling sand-rock, with strings of clay. } *Cyrena deperdita.*
1	0	Ferruginous sand-rock, variable in thickness, with *Limnæa*, &c.
5	0	Concretionary calcareous sand-rock, forms Warden Ledge. } *Limnæa, Potamomya.*
10	0	White and whity-brown sands, *Potamomya* in layers at intervals.
2	0	Stiff grey or sandy clay, with *Potamomya* crowded together.
		Lignitic band.
3	0	Greenish clay. *Potamomya gregaria.*
1	3	Buff-coloured limestone, with *Limnæa.*
		Lignitic or carbonaceous band.
$3\frac{1}{2}$–4	0	Greenish-grey clays.
0	6	Soft crumbling buff limestone, with *Limnæa longiscata.*
2	0	Grey marly clay.
0	8	Buff limestones, with *Limnæa.*
5	0	Greenish clay.
0	6–8	Buff compact limestone, with *Chara*-seeds (*Gyrogonites*) *Chara*-[bed.
2	0	Whity-brown sand-rock, with lignitic band below.
0	4	...Buff limestone, with a few *Chara*-seeds.
		···Carbonaceous layers.
4–$4\frac{1}{2}$	0	Green clay (behind wall at Pier-head).
		...Green clay, a little south of Coast-guard boathouse.
0	6	···Nodular purple-red ironstone band.
1	6	Pale yellowish or whity-brown sands.

Total...... 70–71 feet.

denuded away in the centre of Totland Bay. It cannot, however, have been many feet above the present cliffs near Widdick Chine, while a little south of that it exists in the cliff. At the N.E. corner of Headon Hill we noted it at a height of 70 feet above the sea ; it is well seen also in the cliffs near Heatherwood Point, where it has a somewhat higher elevation.

There is evidence of an anticlinal in Totland Bay, as indicated in E. Forbes's sketchy diagram ; the summit of the anticlinal we infer to be near the old wooden pier.

If we add up, we obtain a thickness for the Lower Headon exposed in Warden Cliff of 71½ feet (supposing no interruption at the point specified above). It remains to settle the relation of the lowest bed here seen to the Upper Bagshot Sands.

The junction of the Lower Headon with the Upper Bagshot is well seen north of Alum-Bay Chine; immediately above the Upper Bagshot sands come greenish-grey clays ; then, in ascending order, alternation of clays and sands ; next, pale greenish-grey sands ; then a stiff marly clay : total 16 feet. Above is a purplish red clay-ironstone band; and succeeding that is the first thin Limnæa-limestone.

If we consider this red iron-band to be at the same horizon as that noticed under Weston Chine, as is extremely probable (though it is some 4 feet nearer to the lowest Limnæa-limestone), then we must add 12 or 16 feet to the 71 feet obtained for the Lower Headon in Warden Cliff, making a total of 83 or 87 feet before we reach the yellowish sand of the Upper Bagshot.

Knowing now the full thickness of the Lower Headon, we are able to test the argument as to the position of the Upper Bagshot, or Headon sands, as they were once called by E. Forbes (Mem. p. 34–6), in Totland Bay. It is stated (*op. cit.* p. 147) that the Survey actually represent these as occurring, in both the Vertical and Horizontal Sections, near the summit of the anticlinal in Totland Bay*.

There seems a little inconsistency in the Survey Vertical Sections concerning both boundaries of the Lower Headon ; if we may classify these green clays in the Lower Headon, and then read off by scale from the top of the How-Ledge bed, the Survey Section would give a thickness of 85 ft. for the Lower Headon in Totland Bay.

It is urged "that the Headon-Hill sands do not occur in the position indicated by the Geological Survey ;" and the crucial test of

* We pointed out above that the Survey Vertical Section [edition 1870] shows them only just above the sea-level at a point some way inland. The Vertical Section we are inclined to interpret in this way—that the beds denoted Upper Bagshot in Totland Bay are what we have classed in the Lower Headon ; for the legend states, below the "clay-ironstone" are 6 inches sand in "Totland Bay," then "green clay with lenticular patches of sand" 15 feet, so that the description agrees fairly with our lowest beds at Heatherwood Point. The Survey Section does not state that these were exposed in the *centre* of Totland Bay ; but as Heatherwood Point is the western point of the bay, we may assume that they may have been seen anywhere short of that point along the base of Headon Hill, where it is quite certain that they exist, and must have been open at that time at more points than one ; for the white glass-house sands were then being actively worked in Headon Hill, and the yellower sands above them may still be seen about a mile from the N.E. corner of Headon Hill.

the excavations at the new Reading Rooms is supposed to prove "that beds are [there] found which have their exact counterpart in the Headon-Hill section, not at the base, but at a much higher part of the series." We can readily understand that the Upper Bagshot sands were not found in the excavation; we could even have predicted the fact beforehand; from a rough calculation, we estimate that the sands are above a dozen feet below the foundation. In favour of this view, we may add that, when the old wooden pier was being made, one of us heard from those engaged in the work, that the piles were driven with difficulty because of their piercing solid sand *.

But putting aside the question as to their exact depth here below the Reading Rooms, we are able to refute the notion that any thing higher than Lower Headon beds exist here. As mentioned above, we recognized immediately behind the Reading Rooms the five Lymnæa-limestones which come below the Potamomya-sand, both at Widdick Chine on the south, and Weston Chine on the north, between which places the sands may be traced almost continuously. The whole of the cliffs between Weston and Widdick Chines are occupied solely and throughout by Lower Headon beds (neglecting the cap of Post-tertiaries). All this part of the section (*op. cit.* pl. vii. f. 2) is inaccurate, in consequence of the Middle Headon being placed too low in Headon Hill.

Middle Headon of Warden Cliff.—Again, we cannot agree with that part of the section between Weston Chine and Warden Point. Here no marine bed is indicated; for in fig. 3, the section drawn to true scale, the Colwell bed is made to die out before the Warden battery is reached, which is occupied by an exaggerated thickness of gravel †.

There is no fact more patent to any observer than that the Colwell-Bay marine bed extends all through Warden Point and Cliff, where it is supported by the How-Ledge limestone. We made a measure in detail of the Colwell marine bed (Middle Headon) at a point about midway between Warden Battery and Weston Chine; it is here $34\frac{1}{2}$ feet thick; we noticed there the Neritina-bed ‡ with its characteristic features and fossils below the Venus-bed as at Colwell Bay and Headon Hill. It would be wearisome to give all the details; but the Colwell bed here is easily recognizable as identical with the Middle Headon of Headon Hill, both physically and palæontologically. At Warden Battery, above the Middle Headon, comes some Upper Headon § besides the Post-tertiary cap.

In the section drawn to true scale (pl. vii. fig. 3) the Colwell-Bay marine bed has its horizontal extension curtailed by almost one

* The iron columns of the new pier are stated to pierce a bluish clay; we should interpret this to indicate the clays immediately above the Upper Bagshot Sands, and which are described as greenish in the Survey section.

† We cannot reconcile this with fig. 2 of the same plate, where the marine bed is more nearly correctly drawn.

‡ Previously noted as bed 16 by Dr. Wright, Proc. Cotsw. Club, i. p. 95, and Ann. & Mag. Nat. Hist. s. 2, vol. vii.

§ Described by Dr. Wright in 1850 as bed 5, Proc. Cotsw. Club, i. p. 90.

half; the result is that the dip is considerably exaggerated. Again, in Headon Hill an exaggeration of dip is produced by the error of 105 ft. in plotting the marine beds. The effect is that the identical bed (Middle Headon) is split into two beds separated by 120 ft. of beds. From our point of view this could only be done by counting more than 100 ft. of beds twice over. In the legend attached to the diagram section fig. 2, "new interpretation," the beds *g* are, in our opinion, the Lower Headon; *f* is the Middle Headon; *e* the Upper Headon; *d* and *c* are the Lower Headon; *b* is the Middle Headon again. According to the old view, which we certainly should prefer, this last 105 ft. has no existence in fact*.

Lower Headon of Colwell Bay.—The section in Colwell Bay is continuous with that of Warden Cliff; but in the bay, as we go north, a few lithological changes occur in the marine beds †, as noticed below, and which cause the marine beds at one part of Colwell Bay to differ far more from the same beds at the centre of the bay than the latter do from the marine beds of Headon Hill. On rounding Warden Point, beyond the sea-wall, is a small rifle-target; and from here the beds are fairly well exposed throughout the bay, though tumbled portions or a diminutive undercliff may conceal some of the beds in places, sufficiently to give considerable trouble in measuring the beds.

The Unio-Solandri bed with *Melania turritissima* has been frequently worked by one of us below the How-Ledge limestone here but this summer we could only find tumbled portions of it. The said limestone rises from beneath the sea-level at How Ledge ‡, whence its appellation, and crosses Colwell Chine; here and at the target it has the same lignitic band and clays beneath it as on the south side of Warden Cliff; it thins down to 3 ft. north of the chine. We mention these upper beds of the Lower Headon to show that the Colwell-Bay marine bed, as at Warden Cliff, reposes on the same succession of beds as in Headon Hill.

Middle Headon of Colwell Bay.—The lowest or Neritina-bed at the S.W. end of the bay, by the target, is now covered by tumbled matter, but is well seen a little further on about 50 yards short of Colwell Chine. Here, *i. e.* between the target and the chine in the

* The diagram in Forbes's posthumous work is so schematic that it omits the higher part of Headon Hill, and, perhaps for clearness sake, the effect of the anticlinal is exaggerated. It is rather severe to treat it as if it were drawn to scale, and, because the Upper Bagshot Sands were brought up too much in the centre of the roll, to say that E. Forbes was "mistaken in his interpretation" (*op. cit.* p. 176) of the beds. Forbes's diagram, in fact, with this qualification, represents the beds in their right position; thus the Lower Headon, no. 6, occupies the summit of the cliffs in the centre of Totland Bay, while no. 7, Middle Headon, is denuded from above it—all which is perfectly correct.

† Since Warden Battery has been built it is forbidden to search for fossils on the slopes at Warden Point. Many years ago one of the authors was in the habit of frequently exploiting the beds here for fossils, and many of them are incidentally described by Dr. Wright, Proc. Cotsw. Club, i. pp. 91, 92 (1850). The engineers, however, have not succeeded in grassing all the slopes, and fallen fossils may still be picked up at the base.

‡ Bed 18 of Dr. Wright, who describes it correctly in Warden Cliff, but appears to have mistaken its position in Headon Hill (*ib.* p. 95).

Marine series above the Neritina-bed, is some foxy-coloured sand-rock, while lenticular layers of white sand are seen thinning out in the grey clays, which also contain red-clay ironstone nodules, a different lithological condition from what occurs further north in the bay, or to the south of Warden Point. Above comes the richest part of the Venus-bed with abundant *Cytherea incrassata*; these fossils not only strew the tumbled clays, but with other fossils are commingled by the waves with recent shells on the strand. At this point of the bay *Ostrea velata* is very abundant above the part richest in *Cytherea*.

In the centre of the bay between Colwell and Bramble Chines this oyster is in extraordinary abundance; at one place it nearly crowds out most of the other fossils, and forms a massive oyster-bank about 21 ft. thick *, of which the lower 12 ft. is almost made up of these shells. The ordinary character of the Venus-bed is quite altered here, though its fossils occur mixed up with the oysters; we may notice as especially abundant *Murex sexdentatus, Pisania labiata, Natica labellata, Nerita aperta, Cerithium variabile, Ostrea velata, Nucula headonensis, Cytherea incrassata*, &c. On either side of this spot, near both How Ledge and Bramble Chine, the excess of oysters has disappeared, and they are chiefly abundant in a zone above the richest part of the Venus-bed, though they do occur sparingly throughout. *Cytherea incrassata* occurs through several feet, but the richest part of the Venus-bed consists of about 9 inches of bluish-green sand; in this the shells are found in the best state of preservation. Above the grey and greenish-grey sandy clays richest in marine forms are some pale bluish-green clayey sands, between Bramble and Linstone (or Lynchen) Chines; in these, at the level of about 5 feet from the base, is a band very rich in *Cerithium ventricosum, C. variabile, Melania muricata, Corbicula obovata*, with, occasionally, *Nerita*; this bed is seen just beyond the spring at Linstone Chine, it is only a few feet below the base of the Upper Headon. We wish to draw attention to the first-named fossil, as it occurs also near the top of the marine beds at Headon Hill, *i. e.* in quite an analogous position.

Upper Headon of Colwell Bay.—The slate-coloured grey clay with *Potamomya* † (immediately succeeding the bluish-green sands) we take as the base of the Upper Headon. A detail vertical section is given (fig. 3), in order to show the lithological differences existing between the series here and equivalent beds in Headon Hill. We do not, however, think them greater than the differences already noticed as occurring in the marine series in different parts of Colwell Bay, while the resemblances are sufficiently great to allow of their perfect correlation—not to mention their position between the Osborne beds above (so identical with the Osborne beds of Headon Hill) and the marine series below, which we have shown, on stratigraphical grounds, is most certainly identical with the Middle Headon of Headon Hill. The differences consist here in a greater development of sand and a reduction of limestone: the sands at the base

* Bed 12 of Dr. Wright (*ib.* p. 92), who, however, much underrates its thickness.
† Base of bed no. 5 of Dr. Wright (*ib.* p. 91).

Fig. 3.—*Vertical Section of Upper Headon Beds in Colwell Bay.*
(Scale, 8 feet to 1 inch.)

UPPER HEADON.

ft. in.		
15 0	Light-grey clays, with layers of shells.	*Paludina lenta, Potamomya gregaria,* &c.
	Pale brownish-grey and light-brown clays in alternations.	
0 6-9	Nodular band of ferruginous sand-rock.	*Corbicula obovata, Cyrena Wrightii.*
2 4	Whitish sand above, yellow and rusty sand below.	*Cyrena Wrightii, Paludina lenta, Corbicula obovata, Melanopsis fusiformis.*
1 4	Buff-coloured *Limnæa*-limestone, with carbonaceous layer below.	
1 6	Pale greenish-grey clays.	
4 0	Zone of *Cerithium trizonatum.* Pale greenish clay. Ferruginous sand layer. Paler sandy clays.	
1 0	Stiff slate-coloured grey clay.	*Cyrena Wrightii, Corbicula obovata, Melanopsis fusiformis, Paludina lenta.*
5 6	Varying alternations of paler and darker grey clays.	
15 0	Pale buff-coloured sands, with lignitic or carbonaceous bands. Greyer sands below. *Potamomya.*	

Total...... $46\frac{1}{2}$ feet.

are considerably thicker here than at Headon Hill; their character is very variable even in different parts of Colwell Bay. The Limnæa-limestone has here a much reduced thickness, as mentioned previously.

Among the other beds we may specially notice the horizon of *Cyrena Wrightii*; it occurs in the nodular ferruginous sand-rock with *Corbicula obovata*, also in the sand immediately above the Limnæa-limestone, and again in some of the clays below. Another fossil that we have only observed at one horizon is the *Cerithium trizonatum* (Morr.); it occurs in the pale greenish clays beneath the limestone, occupying only a narrow band in these clays. Equally characteristic is *Serpula tenuis* (Sow.), which occurs at the same horizon both here and at Headon Hill, viz. in the Upper Potamomya-clay just above the limestone.

The Paludina-clays at the top are identical with those of Headon Hill at the top of the thick limestones. Measurement by tape here gave 15 feet; total of the Upper Headon near Cliff End 46½ feet.

Osborne Beds of Cliff End.—The red and greenish mottled marls of the Osborne series follow. These beds show for a few yards only, and then become hidden under the grass which the engineers have grown on the artificial slopes below the battery. One of us well remembers the numerous little faults (14 are enumerated by the Survey, as cited above) which repeated the Limnæa-limestone. Beyond the battery the Osborne beds form the tumbled cliff; a measurement is no longer to be made with profit. Mr. Bristow gives 62 feet for the series here.

III. Palæontological Evidence.

The question now arises, Does the distribution of fossils bear out the separation of the Colwell-Bay and Headon-Hill marine beds and their reference to different horizons? and does it sanction the notion of the Brockenhurst bed being equivalent to the Colwell-Bay bed?

Two lists of fossils are laid before us, viz. one which mixes up the fossils from the Brockenhurst, Whitecliff Bay, and Colwell-Bay localities, and the other which gives those from the marine beds of Headon Hill and Hordwell Cliff; of the hundred forms (in round numbers) which occur in the latter list, it is said (*op. cit.* p. 150) "less than one half occur at the other three places."

We may urge at the commencement that it comes rather near to begging the question to mix up Colwell-Bay with Brockenhurst-series localities. We conceive one of the main points in dispute to be whether the Colwell-Bay bed has any more affinities with the Brockenhurst fauna than has the Headon-Hill bed; and to this subject we shall address ourselves after we have first compared the fauna of the Colwell-Bay and Headon-Hill marine beds.

The first thing to be done is to separate the faunas of all the localities which are to be compared together; this we have done in the lists at the end of this communication. These have been drawn up from an inspection of the Edwards collection of Tertiary fossils in the British Museum †, while we have added many occurrences from our researches this summer, and we believe our list to be fairly correct.

We do not admit that the Edwards collection is sufficient for a full knowledge of the distribution of English Tertiary fossils: *e.g.* if a certain shell does not exist in the Edwards collection from Colwell Bay, it is no proof that it does not occur there, but simply that Mr. Edwards had better specimens of it from Headon Hill, which was considered, as, indeed, it is, an equivalent bed. The greater part of the Edwards collection was made by the hands of one of the authors; but we do not think it possible to establish from this collection that Colwell Bay contains so many marine forms which do not occur in Headon Hill, and therefore that the marine beds at these localities are not on the same horizon.

The following reasons induce us to say this:—It was the habit of the local collectors to exploit the Colwell-Bay bed far more than the Headon-Hill locality, because it was more accessible and showed a larger extent exposed; the fossils were better preserved, and in every respect it was easier to collect from. Again, some species which one of us supplied to Mr. Edwards from Headon Hill were not incorporated in this collection, probably owing to his having better ones from Colwell Bay; and doubtless they were exchanged with foreign correspondents or given away. These two considerations would serve to account for his Colwell-Bay collection being richer than his Headon-Hill one. Corroborative of this is the fact that in a few days' search this summer we have found several species in the marine bed at Headon Hill which do not exist in the Edwards collection from that locality.

Moreover we hold that the best test as to the contemporaneity of these beds is not to be obtained from the rarer forms, which may be evidenced only by a single example, but from a comparison of the commoner, which we should consider the more characteristic forms. Accordingly we add a list of the species obtained by us this summer from the Middle Headon of both localities: H indicates Headon Hill; C the equivalent bed at Colwell Bay.

List of all the Shells obtained *on the ground* by the authors for the purposes of this paper (Aug. 1880).

(Those with an asterisk pass up from Barton beds.)

*Lamna contortidens (*Ag.*) ...	C, H.
Marginella vittata (*Edw.*)......	H.
*Voluta spinosa (*Lam.*)	C, H.
Pleurotoma headonensis (*Edw.*).	C, H.
*—— denticula (*Bast.*), var. odontella (*Ed.*)	C, H.
*Borsonia sulcata (*Rou.*).........	C.
*Rimella rimosa (*Sol.*)	C, H.
Murex sexdentatus (*Sow.*)......	C, H.
—— sp.	H.
Pisania labiata (*Sow.*)	C, H.
*Cominella flexuosa (*Ed. MS.*)	C, H.

† We are greatly indebted to the Keeper of the Geological Department, Dr. H. Woodward, F.R.S., for his courtesy in allowing us access to the collection, even during the laborious process of packing up and moving the national collection to the new building at South Kensington.

List of Shells (*continued*).

*Ancillaria buccinoides (*Lam.*) C, H.
*Natica Studeri (*Bronn*)......... C, H.
*—— labellata (*Lam.*) .... C, H.
Cancellaria muricata (*Wood*) C, H.
—— elongata (*Nyst*)............ C, H.
Odostomia gracilis (*Ed. MS.*) C.
Scalaria tessellata (*Ed. MS.*)... C.
*Cerithium variabile (*Desh.*) ... C, H.
*—— pseudocinctum (*d'Orb.*) C, H.
—— duplex (*Sow.*) .... H.
—— ventricosum (*Sow.*) ...... C, H.
—— varians (*Ed. MS.*) ...... C, H.
—— (Vicarya) concavum (*Sow.*) .... C, H.
Melania fasciata (*Sow.*)......... C, H.
—— muricata (*Sow.*) .... C, H.
Hydrobia bulimoides (*Ed. MS.*) C, H.
Melanopsis subfusiformis (*Morr.*) .... C, H.
—— fusiformis (*Sow.*) .... C, H.
Actæon dactylinus (*Ed. MS.*). C.
Nematura parvula (*Desh.*) ... C, H.
Nerita aperta (*Sow.*) .... C, H.
—— zonula (*Wood*) .... C, H.
Neritina concava (*Sow.*) ...... C, H.
Bulla æstuarina (*Ed. MS.*) ... C, H.
Limnæa longiscata (*Sow.*)...... C, H.
Planorbis euomphalus (*Sow.*) C, H.
—— obtusus (*Sow.*) .... C, H.
Paludina lenta (*Sow.*) .... C, H.
Ostrea velata (*Wood*) .... C, H.
*Mytilus affinis (*Sow.*) .... C, H.
*Trigonocœlia deltoidea (*Lam.*). C, H.
Leda propinqua (*Wood*) ...... C, H.
Nucula headonensis (*Forbes*) C, H.
—— nudata (*Wood*)............ C, H.
Lucina (Strigilla) colvellensis (*Ed. MS.*)...................... C, H.
Cytherea suborbicularis (*Ed. MS.*)...................... C, H.
*—— incrassata (*Sow.*) .... C, H.
Tellina headonensis (*Ed. MS.*) C, H.
[*]Psammobia compressa (*Sow.*), var. æstuarina (*Ed. MS.*)... C, H.
—— rudis (*Lam.*) .... C, H.
Mactra fastigiata (*Ed. MS.*)... C, H.
*Mya angustata (*Sow.*)=producta (*Ed. MS.*) .... C, H.
*Corbula cuspidata (*Sow.*) ...... C, H.
Corbicula obovata (*Sow.*) ...... C, H.
Cyrena cycladiformis (*Desh.*). C, H.
*Balanus unguiformis (*Sow.*). C, H.
Callianassa Baylii (*Woodw.*). C, H.

Faunas of Middle Headon from Colwell Bay and Headon Hill compared.

The above list contains only the commoner forms, such as may be found in a few days' search. Out of a total of 58 species it will be observed that all but 7 were found by us in both localities *, and all but three are known to be common, or, again, a proportion of 94 per cent. of commoner Colwell-Bay forms occur at Headon Hill †. Surely from this we may presume a very close affinity if not identity of these beds. It is stated (*op. cit.* p. 150) that less than one half of the Headon-Hill and Hordwell species occur at Colwell Bay—a result, it seems to us, only obtained by mixing up fossils from Brockenhurst and Whitecliff Bay in the same list with the Colwell forms. We shall show below that the fossils cited from these two latter localities belong to a lower zone.

Next as to the statement that at Colwell Bay "the strata are of purely marine origin" while "the so-called Middle Marine beds of Headon Hill and Hordwell Cliff are of totally different character"

* Some of these do not exist from both localities in the Edwards collection, and have not found their way into the Headon-Hill and Hordwell list in the paper referred to, though previously cited by Dr. Wright from Hordwell (*ib.* p. 124).

† Comparing the whole known fauna from the Middle Headon of Colwell Bay and Headon Hill, we obtain the following result, viz. 74 per cent. of the Colwell-Bay marine forms have been found at Headon Hill. This is counting as separate species many names in the Edwards collection which are founded on imperfect and single specimens. As we have said, we think a surer guide in comparing faunas is to take only the characteristic and less rare species.

&c. (*l. c.* p. 148). Of the brackish-water genera which are supposed to be found in Headon Hill only, we may remark that we found *Cerithium*, *Cyrena*, *Hydrobia*, *Limnæa*, *Paludina*, *Planorbis*, *Melania*, and *Melanopsis* fully as plentiful in the marine series of Colwell Bay as at Headon Hill; *e. g.* in a quarter of an hour we turned out half a dozen specimens of *Limnæa longiscata** from the richest nine inches of the Venus-bed, the best zone for *Voluta*, *Cancellaria*, *Murex*, *Cytherea*, &c. It has always been the opinion of one of us, who has worked these beds for so long, that these freshwater forms were either drifted down by flood-waters or were dead shells washed out of lacustrine or brackish deposits. They cannot have lived in the waters depositing the marine bed at Headon Hill any more than at Colwell Bay.

Another argument brought forward in opposition to the views of the Geological Survey is, that certain species of *Cerithium* are confined to Headon Hill and do not occur in Colwell Bay; and by this means have been "detected the serious errors which have crept into our classification and correlation of the strata we are now considering" (*op. cit.* p. 149). *Cerithium ventricosum* and *C. concavum* are said to be entirely confined to the Headon Hill and Hordwell localities. We cannot agree with the statement as to the distribution of *C. ventricosum* in the Headon-Hill beds and its "prodigious abundance." It is there, as far as we have observed, found only in one bed; moreover, it is equally abundant in a bed in a precisely similar position at Colwell Bay, viz. at the top of the Middle Headon. Its analogous position in these two localities we consider as fossil evidence confirmatory of the stratigraphical.

Nor do our observations confirm the statement of "prodigious abundance" of *C.* (*Vicarya*) *concavum* at Hordwell Cliff in the Middle Headon. One of the authors who worked that bed when a special excavation was made for the purpose †, considers that *V. concava* was extremely rare in the Hordwell bed; but, as is well known, it occurs abundantly in the Upper Bagshot sands further west at Long Mead End.

As to the supposed absence of *V. concava* from Colwell Bay, we remark that we had not been many minutes at work on the richest portion of the Venus-bed before we found a specimen, subsequently followed by a dozen more. It can scarcely be maintained, therefore, that the Colwell-Bay bed does not belong to the *C.-concavum* zone. This species is here, however, not so common as at Headon Hill ‡.

* Also noticed by Mr. Bristow, F.R.S. (Mem. 10*, p. 61), as well as by previous writers.

† The Middle marine or Middle Headon bed at Rook Cliff, Hordwell, has not been exposed for the last twenty-eight years; it is covered up by a great thickness of gravel, and its precise position is known but to few geologists. It was quite a thin bed, but rich in fossils, especially minute forms. Fossils in existing collections were all obtained about a quarter of a century ago.

‡ This species exists, however, in the Edwards collection, labelled as from Colwell Bay. The absence of a shell in the Edwards collection from Colwell Bay is no proof that it did not occur there; the local dealers might not have thought of picking up *V. concava* at Colwell Bay. For this species they went to Headon Hill, where it was more abundantly found and in better preserva-

Summary.—There is but one marine bed here, namely that in the Middle Headon; for the Colwell-Bay bed *can be traced stratigraphically* into the Headon-Hill Venus-bed, and the palæontological evidence is in harmony with the stratigraphical. The place of the Brockenhurst bed is at a lower horizon in the Middle Headon; but it does not appear anywhere in the west end of the island.

IV. Whitecliff Bay and New Forest.

Middle Headon of Whitecliff Bay.—We next have to raise a more serious objection to the way in which the Whitecliff Bay section has been interpreted. In mixing up all the beds in the marine series there together and calling them Brockenhurst series, it seems to us that the question has been obscured, if not begged. The statement is that the 100 feet of marine beds at Whitecliff Bay are the equivalents of the 25-feet of marine beds at Colwell Bay and of the beds in the New Forest with the Brockenhurst fauna (*op. cit.* p. 148). Hence the Colwell-Bay bed is placed in the Brockenhurst series, which is said to occupy a higher horizon than the Headon-Hill and Hordwell marine bed; and this view is indicated by dotted lines in the vertical sections on p. 170. Since the 100 feet of marine beds are classed together and called "Brockenhurst Series," we suppose that the Brockenhurst fauna is imagined to occur throughout them. As a matter of fact, that fauna is confined to one zone, and that the very base of the series.

Though we have worked over this part of the section bed by bed, we need not here give all the details, but will refer to the description of it on the Survey Vertical Section on Sheet 25. This series is there justly referred to the Middle Headon, since it lies between the freshwater Lower and Upper Headon, its total thickness read off by scale being 90 feet. At the top are clayey sands and yellow sands about 19 feet; then the "Venus-bed" clays &c., 15 feet; next, below, are compact sands with nodules about 42 feet, said to contain *Sanguinolaria Hollowaysii* *; then come 14 feet of brown clays, the base "greenish and brownish clay, very fossiliferous." Now there is no doubt at all about the bed above and the Venus-bed here being any thing but the Colwell-Bay and Headon-Hill marine bed—its position and its fossils prove that; the characteristic Brockenhurst fossils are absent from it, and it is therefore certain that it differs entirely from the Brockenhurst beds.

The Sanguinolaria-sand differs lithogically from the lower part of the marine series, both at Colwell Bay and at Headon Hill. Such few fossils as we observed in it are distinctive, not of the Venus-

tion. Moreover these collectors sought to obtain as many forms as possible, but were not concerned in finding the same species in both localities; and if they found only a few stray examples at one locality of a species of which they had a great number from the other, they were liable not to put a separate label for the odd few, but to mix them up with the larger parcel.

* A wrong determination; the shell is *Psammobia compressa*, var. *æstuarina*, Ed. MS. It occurs in the natural position of life, *i. e.* across the bedding.

bed, but of Brockenhurst beds; but though we have not sufficiently worked out this fauna, we may say that we are satisfied that they belong to a lower zone than any of the marine beds at Colwell Bay or Headon Hill, the Middle Headon being more fully developed at Whitecliff Bay than elsewhere.

Brockenhurst Zone at Whitecliff Bay.—The succeeding 14 feet are the equivalents of the Brockenhurst beds; the lowest two feet we shall call the Brockenhurst zone; the remainder of the thickness is not nearly so rich in species, and their grouping, as well as the lithological character, is more like that of the Roydon beds.

At the time the Survey section was made, the interesting bed at Brockenhurst had not been discovered nor its fauna described; hence such Brockenhurst fossils as were found in this zone here were not rightly determined (thus in the Survey section we must read *Cardita deltoidea*, Sow., for *C. acuticosta*), or specific names were withheld from them. Subsequent observers* have recognized the Brockenhurst fauna in this lowest bed. As we have obtained more fossils from it than previous observers, we have embodied our results in a separate column in the lists at the end of this essay; that column contains nothing except what we have collected with our own hands this summer from the lowest two feet†, lying on an eroded surface of the freshwater Lower Headon. Comparison of this list with the fauna from Brockenhurst itself will convince most, we think, of the perfect equivalence of the zone in the island and in the forest, while its position at Whitecliff Bay shows that it is at the base of the Middle Headon.

Brockenhurst Zone in the New Forest.—The greater part of the fossils from Brockenhurst were collected by the hands of one of the authors, and thence were dispersed into various public and private collections. They were obtained during the doubling of the line and widening of the cutting at Whitley Ridge, near Brockenhurst‡, about twenty-three years ago. During this work he had the advantage of seeing more of the beds than any other geologist. He found the rich Brockenhurst zone (which varied from a few inches to nearly a foot) lying immediately upon the freshwater Lower Headon; while about half a mile up the line, near the bridge by Lady-Cross Lodge, the Middle Headon Venus-bed was seen, followed by the freshwater Upper Headon beds above, the beds having a very gentle dip up the line or easterly§. It is evident that the succession

* *Videlicet* Von Könen, Quart. Journ. Geol. Soc. vol. xx. p. 98; Rev. O. Fisher, Quart. Journ. Geol. Soc. vol. xviii. p. 67, footnote; Mr. T. Codrington, Quart. Journ. Geol. Soc. vol. xxiv. p. 519; Dr. Duncan, Pal. Soc., 'Fossil Corals,' i. p. 40 (1865).

† In the Edwards collection the label "Whitecliff Bay" includes many Venus-bed forms, indeed Lower and Upper Headon, or it may be any thing from the London Clay to the Bembridge Marls; there is therefore good reason for not allowing this collection to stand as evidence of what is found in the Brockenhurst zone at Whitecliff Bay.

‡ The railway-cutting at Brockenhurst (*op. cit.* p. 152) refers to the same spot as Whitley Ridge.

§ We visited the New-Forest localities together this summer, and found the Whitley-Ridge cutting entirely grassed over (the rich zone was below the level here is, in ascending order, freshwater Lower Headon, Brockenhurst zone, Venus-bed, then freshwater Upper Headon, which agrees with the succession in Whitecliff Bay. Yet in the New-Forest section (*op. cit.* p. 170) we find the Brockenhurst bed placed above the marine band or Middle Headon of Totland Bay—in other words, the natural succession is inverted.

Again, in Headon Hill as we have seen, an imaginary Brockenhurst bed (of which the Colwell-Bay Middle Headon is stated to be the equivalent) is placed above the Upper Headon, in ground which is really occupied by the Osborne beds. If the Brockenhurst bed is at a higher horizon than the Middle Headon of Headon Hill, then where is the marine Middle Headon at Whitecliff Bay?

We can scarcely adopt a theory which makes the Colwell-Bay bed occupy a higher horizon than that of Headon Hill, because it is supposed to contain more Brockenhurst fossils, when the latter fauna is found below the zone with (Colwell-Bay or) marine Headon fossils both at Whitecliff Bay and near Brockenhurst. When once the position of the Brockenhurst fauna is recognized (and it has been correctly described by previous observers), the inconsistency of the theory is apparent.

Affinities of the Brockenhurst Fauna.—Seeing that the Brockenhurst fauna, if different in age from the Marine Headon, is older, instead of being younger, it would be rather anomalous to find that "while nearly *one third* of the Hordwell and Headon-Hill marine shells are Barton forms, not more than *one fifth* of those occurring at Brockenhurst, Colwell Bay, and Whitecliff are found at Barton." We have already mentioned one feature in the lists on which this statement is based by which the question is almost begged. We must next allude to what seem to us clerical errors, in order to justify the very different statistics which we have obtained by inspection of the Edwards collection, supplemented by our own researches.

In the Headon-Hill list we observe nine species * that are said to pass down into Barton beds, while in the Brockenhurst list this range is denied to them; and besides these nine, the range into Barton, as proved by the Edwards collection, is omitted in the Brockenhurst list in the case of twenty-two other species. Discrepancies of this sort must seriously detract from the value of any statistics based on such lists.

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of the rails, and will never be seen again here); the upper beds were yellowish clayey sands, poor in fossils. Sufficient characteristic Brockenhurst fossils may still be seen, however, on the old spoil-banks of the date of the making of the original single line, about forty-two years ago. By Lady-Cross Bridge the cutting is also grassed over; but evidence can still be found of the Venus-bed in the side drains and of the Upper Headon in the slopes above it.

* These species are—*Borsonia sulcata, Nematura parvula, Mytilus strigillatus, Cardium obliquum, Trigonocœlia deltoidea, Lucina obesa, L. concava, Panopæa subeffusa,* and *Scintilla angusta.* On the other hand, an error on the opposite side, omitting the range into Barton beds in the case of *Marginella simplex* and *Corbula cuspidata,* goes only one quarter of the way towards redressing the balance.

So far from the Brockenhurst zone having fewer forms common to the Barton than the Headon-Hill marine bed, we consider that it has rather more, as its position at the base of the Middle Headon at Whitecliff Bay would lead us to expect. Thus, if we take the whole Brockenhurst fauna (including the 15 corals which are mostly special to the zone), we obtain a total of 151 species, of which from 74 to 81 pass up from Barton, or a proportion of about one half. Summing up the Headon-Hill forms in the same way—out of a total of 79 species, 23 pass up from Barton beds, or a proportion of 29 per cent. But, instead of including the rarer forms, if we take only the more characteristic and abundant species of the Brockenhurst zone, it would be perhaps a preferable course.

The following list is a catalogue of the fossils in the Woodwardian Museum from the Brockenhurst zone, obtained by one of us many years ago at Whitley-Ridge railway-cutting, New Forest; and it may be taken to include the chief characteristic fossils of the zone. We have found all, except two, in the 2-feet bed at Whitecliff Bay this summer.

*Hippocrenes (Rostellaria) ampla.
*Rimella rimosa.
Murex hantoniensis (*Ed. MS.*).
*Typhis pungens.
*Strepsidura armata.
Cancellaria muricata.
Pisania (Fusus) labiata.
*Clavella (Fusus) longæva.
Leiostoma ovatum.
*Cassis ambigua.
*Ancillaria buccinoides.
Pleurotoma transversaria.
—— cymæa.
—— headonensis.
*—— denticula.
*—— pyrgota.
*Voluta decora (*Beyr.*) = maga (*Ed.*).
*—— spinosa.
—— suturalis.
—— geminata.
*Actæon simulatus.
Marginella æstuarina.
*Natica hantoniensis.
*—— Studeri.
*—— ——, var. grossiuscula (*Ed. MS.*).
*—— labellata.
Chenopus Margerini, var. speciosus.
*Infundibulum trochiforme = obliquum (*Sow.*).
Phorus cretifer (*Ed. MS.*).
Ostrea ventilabrum = prona (*S. Wood*).
*Anomia tenuistriata.
Pecten bellicostatus.
Modiola Nysti.
*Avicula media.
*Lucina bartonensis (*Ed. MS.*).
* Cardium porulosum.
Protocardium hantoniense (*Ed. MS.*).
Cardita deltoidea.
*Cytherea incrassata.
—— suborbicularis (*Ed. MS.*).
*—— Solandri.
Cyprina Nysti.
[*]Crassatella Sowerbyi, var. hantoniensis (*Ed. MS.*).
*Corbula ficus.
*—— cuspidata.
[*]Psammobia compressa, var. arcuata (*Ed. MS.*).
Panopæa sulculosa (*Ed. MS.*).
Madrepora anglica.
Dendrophyllia.
Lobopsammia cariosa.
Balanophyllia granulata.
Solenastræa cellulosa.

Of this shorter list a proportion of about 50 per cent. pass up from Barton or Bracklesham beds; so that, taking the whole fauna or the more characteristic members of it only, in either case nearly one half pass up from Barton beds—a very different thing from one fifth, which was the proportion given in the paper referred to (*op. cit.* p. 150). If we compare with this the ratio of Barton forms in the list of commoner Headon-Hill given above (*supra*, p. 105), we find that 30 per cent. pass up from Barton beds (while in the complete list of the Headon-Hill fauna the porportion is also about 29 per cent.). Moreover, if we first eliminate the forms that occur also at Brockenhurst, so as to obtain what we may consider as specially Headon species, the proportion becomes even lower. On all hands the palæontological evidence seems perfectly in accord with the stratigraphical.

Relation of Colwell Marine to Brockenhurst Fauna.—In order to see whether the Colwell bed is more nearly related to the Brockenhurst than is the Headon-Hill bed, we will first take the proportion of Barton forms in it for comparison with similar treatment of the Headon-Hill catalogue. Examination of the list gives us a proportion of 29 per cent. of Barton forms in the Colwell-Bay bed; we saw above that, in the Brockenhurst bed, the ratio was about 50 per cent. and in the Headon marine bed 29 per cent. An inspection of the list of more characteristic Colwell and Headon marine fossils (*suprà*, p. 105) showed that these faunas are practically identical Now we see that their proportion of Barton forms is nearly equal, and far lower than in the Brockenhurst bed.

To complete the proof from fossils, if any such is needed, we may inquire whether there are more Brockenhurst forms peculiar to Colwell Bay than to Headon Hill. Examination of the lists shows that only the following Brockenhurst species occur at Colwell Bay and not at Headon Hill, viz. *Scalaria tessellata* and *Tellina affinis*, the latter passing up from Barton beds; while those occurring at Headon Hill and not at Colwell Bay are *Marginella æstuarina* and *Cardita paucicostata*—two only in each case, which amounts to perfect equality. If, on the other hand, we count those common to the Colwell and Headon marine beds, and not occurring at Brockenhurst, we find twenty-six species in this category. We are at a loss to understand how any one could imagine that the Brockenhurst fauna is identical with that of the Colwell-Bay bed and newer than that of Headon Hill.

That the Colwell-Bay bed is stratigraphically identical with the Headon Middle Marine we hope that we have sufficiently proved; and the fact is confirmed by fossil evidence. The same twofold proof has been brought forward to demonstrate that the Brockenhurst bed, where present, lies at the base of the marine Headon beds and immediately above the Lower Headon. This bed is absent at Colwell Bay and Headon Hill, but is seen at Whitecliff Bay, Brockenhurst, and Lyndhurst.

Since the Middle Headon includes every thing between the freshwater Upper and Lower Headon, it must be allowed to include the Brockenhurst beds, though that special fauna was not known when names were given to these groups of strata. It would cause the greatest inconvenience to abandon the term Middle Headon, as it would entail the abandonment of the names Upper and Lower also. There is therefore no room for the term "Brockenhurst Series" in the sense proposed in the paper referred to (*op. cit.* p. 168)—a classification which would be in conflict with the best authorities, and founded, as we have endeavoured to show, on a defective appreciation of the beds. We may urge that no new facts have been discovered concerning the succession of the strata to make any correctionary classification or nomenclature in the main groups of the Upper Eocene at all necessary or desirable, and we should prefer to retain the local groupings which have been so long familiar to geologists. We may denote as the "Brockenhurst Beds" the lower part of the Middle Headon with the rich Brockenhurst fauna. It is not always developed; the absence of admixture of fresh water was evidently the necessary condition of its abundance of marine mollusca and of the existence of its corals.

It may perhaps be subdivided into the "Brockenhurst zone" and the "Roydon zone"*. The correlation of this fauna was justly made

* We found the Roydon brick-yard pit in a good state for examination this summer, and obtained from it twenty-eight species. They all came from the sandy clays with bands of iron-ore septaria; the lowest beds were below the level of the standing water. The section is as follows:—

Gravel, Post-Tertiary.

2–3 feet.	Bluish to yellow-grey clay.	
9 inches.	"Shell-bed;" clay very full of shells.	*Murex sexdentatus*, *Cardita oblonga* var. *transversa*, *Pisania labiata*, *Trigonocœlia deltoidea*, *Ostrea velata*, *Cytherea incrassata*, *Cyrena obovata* var. *subregularis* (Ed. MS.).
7½ feet.	Grey clay. Two nodule-bands of iron-ore septaria separated by grey sandy clay. Stiff bluish clay for the lower 2 feet.	*Voluta geminata*, *Voluta spinosa*, *Strepsidura armata*, *Pleurotoma transversaria*, *Pleurotoma hantoniensis*, *Natica epiglottina*, *Bulla Lamarckii*, *Protocardium hantoniense*, *Cytherea suborbicularis*, *Psammobia æstuarina*, *Corbula pisum*, &c.
7 feet.	Greenish-grey clayey sands.	

Reposing on Lower Headon fresh-water clays.

The shelly bed, we consider, represents part of the Venus-bed or Headon-Hill marine zone, since it contains the characteristic oyster and *Murex sexdentatus*, &c.

The clays and clayey sands below, of which we examined 7½ feet, while, according to the statement of the men employed, the remaining sandy beds below are another 7 feet, we propose provisionally to term the "Roydon zone." It is characterized palæontologically by the abundance of *Voluta geminata*, differing from the "Brockenhurst zone" by the absence or great rarity of *Voluta suturalis*, *Pleurotoma cymœa*, and *Cytherea Solandri*, for the latter shells are by Von Könen in 1864, and by Dr. Duncan for the corals in 1866, whose work is not in any way affected by any thing in the present essay. We have merely striven to prevent the beds in the Isle of Wight and the New Forest being thrown again into confusion, and the accurate work of E. Forbes and the Geological Survey being rejected on such insufficient grounds as have been recently put forward.

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abundant in that rich zone, a few inches thick, in the Whitley-Ridge railway-cutting.

At the time of obtaining the Roydon fossils in the Edwards collection, one of the authors sank a pit to the base of these beds, and they were found lying immediately on the freshwater Lower Headon clays, the Brockenhurst zone being absent; the latter has apparently thinned out here, as the Roydon zone itself thins out a little further west.

Of the White-Cliff-Bay beds we are disposed to place in the Roydon zone all those between the "Venus-bed" clays of the Geological Survey Vertical Section and the lowest two feet of sandy clays lying immediately on the eroded surface of the freshwater Lower Headon, which said bed we have described above as the "Brockenhurst zone." The Roydon zone will thus include the 42 feet of yellow and green sands with ironstone-nodules, of which the chief fossil is *Psammobia æstuarina* (=*Sanguinolaria Hollowaysii* of the Geological Survey Section), also the remaining 12 feet of beds described in the legend as "brown clay," but which in their unweathered condition are slate-colour to greenish grey.

We had unfortunately not sufficient opportunity to work out the fauna completely; but such fossils as we found induce us to parallel these beds with those of the Roydon brick-pit. The lithological character of these lower beds, as seen below low-water mark at equinoctial tide, is singularly like the clayey sands of the Roydon brick-yard, while their chief fossils are the *Psammobia*, lying in the natural position of life, and *Cardita deltoidea*. At some future time we hope to work out the fauna more completely.

At Cutwalk hill, Lyndhurst, both the Brockenhurst and Roydon zones occur. In the pits which one of the authors sank in obtaining fossils for Mr. Edwards and others from this locality, the Brockenhurst zone was found lying, as usual, immediately on the freshwater clays of the Lower Headon.

Hence we may divide the Middle Headon into three zones, distinguishable easily by fossils (though, of course, many species are common to all three), viz. the Brockenhurst, the Roydon, and the Venus-bed or Headon-Hill zone. The percentage of Barton forms diminishes as we ascend in the series.

Fossils of the Middle Headon series, including the Brockenhurst beds †.

	Middle Headon.							Upper Bagshot.
				Brockenhurst beds.				
	Hordwell.	Headon Hill.	Colwell Bay.	Roydon.	Whitecliff Bay.	Lyndhurst.	Brockenhurst.	Long Mead End.
*Lamna contortidens (*Ag.*)	...	*	*	*	K.T.	...	K.T.	
Marginella simplex (*Edw.*)	...	...	*	...	...	...	...	*
—— æstuarina (*Edw.*)	...	*	...	*	...	*		
—— vittata (*Edw.*)	...	*						
Voluta geminata (*Sow.*)	...	...	...	*	K.T.	*		
—— —— var. tereticosta (*Ed. MS.*)	...	...	...	*	*			
*—— decora (*Beyr.*)=maga (*Ed.*).	...	...	...	...	K.T.	*	*	
—— suturalis (*Nyst*) = contabulata (*Ed.*)	...	...	...	*	K.T.	*	*	
*—— spinosa (*Lam.*)	*	K.T.	*	*	K.T.	*	*	
Mitra gracilenta (*Ed. MS.*)	...	...	...	*				
—— abbreviata (*Ed. MS.*)	...	...	...	...	K.T.	...	*	
—— polygyra (*Ed. MS.*)	...	...	...	...	...	...	*	
[*]Conorbis dormitor (*Sol.*), var. seminuda (*Ed.*)	...	...	...	...	...	*	*	
[*]——procerus (*Beyr.*)=alatus, var. hemilissa (*Ed.*)	...	...	...	*	K.T.	*	*	
Pleurotoma transversaria (*Lam.*)	...	...	...	*	K.T.	*	*	
—— cymæa (*Ed.*)	...	...	...	*	K.T.	...	*	
—— —— var. nana (*Ed.*)	...	...	?*					
*—— pyrgota (*Ed.*)	...	...	...	*	...	...	*	
—— bellula (*Phill.*)	...	...	...	...	...	...	*	
—— Woodi (*Ed.*)	...	*						
—— headonensis (*Edw.*)	*	*	*	K.T.	...	*	*	
*—— denticula (*Bast.*)	...	...	...	...	...	*		
*—— —— var. odontella (*Ed.*) ...	*	*	*	K.T.	K.T.	*		
—— læviuscula (*Ed.*)	...	...	...	...	...	...	*	
—— subdenticulata (*Goldf.*) = hantoniensis (*Ed.*)	...	...	...	*	K.T.	*	*	
* Borsonia sulcata (*Rou.*)	*	*	*	...	K.T.			
—— sp.	...	...	...	...	K.T.			
Chenopus Margerini (*deKon.*), var. speciosa (*Schlot.*)	...	...	...	...	K.T.	...	*	
*Rimella rimosa (*Sol.*)	...	*	*	*	K.T.	*	*	
*Hippocrenes (Rostellaria) ampla (*Sow.*)	...	...	...	...	K.T.	*(?)	*	
Carried forward	4	9	8	15	17	14	18	1

† Those marked with an asterisk pass up from Barton or Bracklesham beds. The asterisk enclosed in brackets signifies that the type species exists in Barton beds, but not the special variety. The initials K.T. denote that the citation is the result of our own researches instead of being founded on the Edwards collection.

Fossils of Middle Headon series, &c. (continued).

	Middle Headon.							Upper Bagshot.
				Brockenhurst beds.				
	Hordwell.	Headon Hill.	Colwell Bay.	Roydon.	Whitecliff Bay.	Lyndhurst.	Brockenhurst.	Long Mead End.
Brought forward	4	9	8	15	17	14	18	1
Murex hantoniensis (*Ed. MS.*)	...	...	...	...	K.T.	*	*	
—— sexdentatus (*Sow.*)	*	*	*					
—— ——, var. cinctus (*Ed.*)	...	...	?*					
*—— minax (*Sol.*)	...	...	...	...	K.T.	...	*	
*—— obtusus (*Desh.*)	...	...	...	...	...	...	*	
—— —— sp.	...	K.T.						
*Typhis pungens (*Sol.*)	...	...	...	...	K.T.	*	*	
Cantharus subcostatus (*Ed.*)	...	...	...	...	...	*		
Fasciolaria crebrilinea (*Ed. MS.*)	...	*						
Pisania (Fusus) labiata (*Sow.*)	...	*	*	*	K.T.	*	*	
—— ——, var. concinna	...	...	*					
*—— nodicosta (*Ed. MS.*)	...	...	...	*				
*—— acuticosta (*Ed.*)	...	...	*					
Phos scalaroides (*Lam.*)	*							
*Clavella (Fusus) longæva (*Sol.*)	...	...	...	*	K.T.	*	*	
Chrysodomus (Fusus) Sandbergeri (*Beyr.*)	...	...	...	...	...	...	*	
Leiostoma ovatum (*Beyr.*)	...	...	...	...	...	...	*	
*Strepsidura (Buccinum) armata (*Sow.*)	...	...	...	*	K.T.	*	*	
—— semicostata (*Ed. MS.*)	...	...	*					
*Cominella (Buccinum) deserta (*Sol.*)	...	...	...	...	K.T.	...	*	
*—— flexuosa (*Ed. MS.*)	...	K.T.	*	...	K.T.	...	*	
—— ventricosa (*Ed. MS.*)	...	...	...	*				
*Ancillaria buccinoides (*Lam.*).	*	K.T.	*	*	K.T.	*	*	
*Cassis ambigua (*Sol.*)	...	...	...	*	K.T.	...	*	
*Natica hantoniensis (*Sow.*)	...	...	...	...	K.T.	...	*	
*—— obovata (*Sow.*)	...	...	...	*				
—— conulus (*Ed. MS.*)	...	...	...	...	...	...	*	
*—— Studeri (*Bronn*)	...	*	*	...	...	*	*	*
*—— ——, var. grossiuscula (*Ed. MS.*)	...	*	K.T.	...	...	...	*	*
*—— epiglottina (*Lam.*)	*	...	...	K.T.				
*—— labellata (*Lam.*)	*	*	*	*	K.T.	*	*	
—— ——, var. dubia (*Ed. MS.*)	...	...	...	...	...	...	*	
Cancellaria muricata (*S. Wood*) =pyrgota (*Ed. MS.*)	*	K.T.	*	*	K.T.	*	*	
—— elongata (*Nyst*)	*	*	*	*	...	*	*	
*—— evulsa (*Sol.*)	...	...	...	...	K.T.			
—— roydonensis (*Ed. MS.*)	...	...	...	*				
*Pyramidella (Turbonilla) obscura (*Ed. MS.*)	...	...	...	*				
Turbonilla plicatella (*Ed. MS.*)	...	...	...	*				
—— semilævis (*Ed. MS.*)	...	...	...	*				
*—— plicatilis (*Ed. MS.*)	...	...	*					
Carried forward	11	20	22	31	31	25	39	3

Fossils of Middle Headon series, &c. (continued).

	Middle Headon.							Upper Bagshot.
				Brockenhurst beds.				
	Hordwell.	Headon Hill.	Colwell Bay.	Roydon.	Whitecliff Bay.	Lyndhurst.	Brockenhurst.	Long Mead End.
Brought forward	11	20	22	31	31	25	39	3
*Turbonilla obliquecostata (*Ed. MS.*)	...	*						
—— dubia (*Ed. MS.*)...............	...	*						
—— sorella (*Ed. MS.*)	...	*						
Odostomia loxodonta (*Ed. MS.*)...	...	*	*					
—— subumbilicata (*Ed. MS.*) ...	...	*	*					
—— geminata (*Ed. MS.*)	...	*	*					
—— multispirata (*Ed. MS.*)	...	*						
—— gracilis (*Ed. MS.*)	...	*	*					
*—— hordeola (*Lam.*)	*							
—— ——, var. angusta (*Ed. MS.*)	...	...	...	*				
Eulima gracillima (*Ed. MS.*)......	...	...	*					
*Cerithium variabile (*Desh.*)	...	*	*	...	...	...	*	*
[*]—— submarginatum (*Ed. MS.*), var. recentior (*d'Orb.*)............	*	...	*	...	...	...	...	*
*—— pseudocinctum (*d'Orb.*)	...	*	*	...	...	*	*	
—— duplex (*Sow.*)	*	*	*					
—— parvulum (*Ed. MS.*)	...	*						
—— pliciferum (*Ed. MS.*).........	...	...	*					
—— ventricosum (*Sow.*)............	*	*	*					
—— subconoideum (*Ed. MS.*) ...	...	...	*					
—— contiguum (*Desh.*)?	...	*						
—— multispiratum (*Desh.*)	...	*						
—— gyrostoma (*Ed. MS.*)	...	*						
—— concavum (*Sow.*)	*	*	*	...	...	...	...	*
—— varians (*Ed. M.S.*)	...	*	*					
Melania fasciata (*Sow.*)	...	*	*	...	...	...	...	*
—— muricata (*Sow.*)	*	*	*					
*—— brevicula (*Ed. MS.*)	*							
*Hydrobia anceps (*Wood*)	*	...	*	...	...	...	...	*
—— Dubuissoni (*Bouillet*), var. rimata (*Ed. MS.*)	*							
—— bulimoides (*Ed. MS.*)	...	K.T.	*					
Melanopsis subfusiformis (*Morr.*)	*	*	*	...	...	...	*	*
—— fusiformis (*Sow.*)	*	K.T.	*	...	...	...	...	*
Scalaria lævis (*Morr.*)...............	...	*	*					
—— tessellata (*Ed. MS.*)	...	...	*	*				
Nematura parvula (*Desh.*)	*	K.T.	*	...	...	...	...	*
—— pygmæa (*Forbes*)	...	...	*					
—— lubricella (*Braun*)	*							
Cæcum Morrisii (*Ed. MS.*)	...	*						
Trochus pictus (*Ed. MS.*)	*							
*Trochita (Infundibulum) trochiformis (*Lam.*) = obliqua (*Sow.*)	...	...	...	*	K.T.	...	*	
Phorus cretifer (*Ed. MS.*)	...	...	...	...	K.T.	...	*	
Teinostoma minutissimum (*Ed. MS.*)	...	...	*					
Carried forward......	25	46	47	34	33	26	44	11

Fossils of Middle Headon series, &c. (continued).

	Middle Headon.							Upper Bagshot.
				Brockenhurst beds.				
	Hordwell.	Headon Hill.	Colwell Bay.	Roydon.	Whitecliff Bay.	Lyndhurst.	Brockenhurst.	Long Mead End.
Brought forward	25	46	47	34	33	26	44	11
Teinostoma micans (*Ed. MS.*)......	...	...	*					
Nerita aperta (*Sow.*)	*	K.T.	*					
—— [æstuarina (*Ed. MS.*)]=N. zonula (*S. Wood*)	*	K.T.	*					
Neritina concava (*Sow.*)	*	K.T.	*	...	...	...	...	*
[*]Rissoa carinata (*Ed. MS.*), var. denticulata (*Ed. MS.*)............	...	*	*					
—— ditropis (*Ed. MS.*)............	*							
Tornatella limnæiformis (*Sandb.*).	*	...	...	*	K.T.			
—— altera (*Desh.*)	...	...	...	...	...	...	*	
—— dactylina (*Desh.*)	...	...	*					
*—— simulatum (*Sow.*)	...	...	...	...	K.T.	...	K.T.	
Adeorbis apertus (*Ed. MS.*)	*							
—— æstuarinus (*Ed. MS.*)	*							
*Orthostoma crenatum (*Sow.*)......	...	...	...	*				
—— retiarium (*Ed. MS.*)	...	...	...	...	K.T.	...	*	
*Ringicula parva (*Ed. MS.*).........	...	...	...	*				
Bulla æstuarina (*Ed. MS.*).........	*	*	*	...	...	*		
—— Lamarckii (*Desh.*)	...	...	...	*	...	...	...	*
—— curta (*Ed. MS.*)	...	...	...	...	...	*		
—— simillima (*Ed. MS.*) [*cf.* æstuarina]	...	...	...	...	...	*		
*—— attenuata (*Sow.*)...............	...	...	...	...	K.T.			
—— navella (*Ed. MS.*)	...	...	*					
*—— Sowerbyi (*Nyst*)	...	...	...	...	K.T.			
—— tenuicula (*Ed. MS.*)	*							
*—— elliptica (*Sow.*)?	*							
Cylichna globulus (*Ed. MS.*)......	...	...	...	*				
—— ovalis (*Ed. MS.*)...............	...	...	*					
Dentalium, sp.	...	...	...	...	K.T.			
*Anomia tenuistriata (*Desh.*)	*	...	...	...	K.T.	...	*	
Ostrea velata (*S. Wood*)	*	K.T.	*					
*—— flabellula (*Lam.*) = ventilabrum (*Goldf.*)	...	...	...	...	K.T.	...	*	
Pecten bellicostatus (*S. Wood*) ...	...	...	...	...	K.T.	...	*	
*Avicula media (*Sow.*)...............	...	...	...	...	K.T.	...	*	
*Mytilus affinis (*Sow.*)	*	K.T.	*					
Modiola Nysti (*Kiehl, MS.*)	...	...	...	...	K.T.	...	*	
—— ignota (*Ed. MS.*)	...	...	...	...	...	...	*	
*Arca biangula (*Lam.*)	...	...	...	...	K.T.	...	*	
*—— appendiculata (*Sow.*)	...	...	..	...	...	...	*	
*—— lævigata (*Caill.*)...............	*	*	*	...	...	*		
*—— duplicata (*Sow.*)=sulcicostata (*Nyst*)	...	...	...	...	...	...	*	
*Trigonocœlia deltoidea (*Lam.*) ...	*	*	*	...	...	*	*	*
Nucula headonensis (*Forbes*)	*	*	*					
Carried forward......	41	56	61	39	45	31	57	14

Fossils of Middle Headon series, &c. (continued).

	Middle Headon.							Upper Bagshot.
				Brockenhurst beds.				
	Hordwell.	Headon Hill.	Colwell Bay.	Roydon.	Whitecliff Bay.	Lyndhurst.	Brockenhurst.	Long Mead End.
Brought forward	41	56	61	39	45	31	57	14
Nucula nudata (*Wood*)...............	...	*	*	*				
*—— similis (*Sow.*)	...	...	...	...	K.T.			
*—— lissa (*Wood*)......................	*	...	...	K.T.				
Leda propinqua (*Wood*)	...	K.T.	*	K.T.	K.T.			
*—— minima (*Sow.*)....................	...	...	...	...	...	...	*	
Cardita simplex (*Ed. MS.*)	...	...	...	*				
—— paucicostata (*Sandb.*)=nodicosta (*Edw.*)	...	*	...	*				
—— deltoidea (*Sow.*)	...	...	...	K.T.	K.T.	*	*	
—— orbicularis (*Goldf.*)	...	...	...	...	...	...	*	
[*]—— oblonga (*Sow.*), var. transversa (*Ed. MS.*)	...	*	K.T.	...	...	...	*	*
——, var. serratina (*Ed. MS.*)	...	*						
[*]Crassatella Sowerbyi, var. hantoniensis (*Edw.*)	...	...	...	*	...	...	*	
*Lucina obesa (*Ed. MS.*)	...	*						
—— concava (*Defr.*)	*	*	*	K.T.	...	...	*	
—— pulvinata (*Ed. MS.*)	*	...	*					
*—— bartonensis (*Ed. MS.*)	...	...	...	...	K.T.	...	*	
*—— inflata (*Ed. MS.*)	*	*	...	...	...	...	...	*
Strigilla colvellensis (*Ed. MS.*) ...	*	K.T.	*	...	...	...	...	*
—— pulchella (*Ag.*)	...	*						
Diplodonta suborbicularis (*Ed. MS.*)	...	...	...	...	K.T.	...	*	
*—— obesa (*Ed. MS.*)	...	...	...	*				
—— planiuscula (*Ed. MS.*)	...	...	...	...	...	...	*	
*Cardium porulosum (*Lam.*)	...	...	...	*	K.T.	...	*	
*—— obliquum (*Lam.*)...............	*	...	...	*				
Protocardium hantoniense (*Ed. MS.*)	...	...	...	K.T.	K.T.	...	*	
*Cypricardia pectinifera (*Sow.*) ...	...	...	...	*	K.T.	...	*	
Isocardia transversa (*Nyst*)	...	...	...	...	...	...	*	
*Scintilla angusta (*S. Wood*)	*	...	*					
Lepton nitidulum (*S. Wood*)	*							
—— tumidum (*Ed. MS.*)	...	...	*					
Cyprina Nysti (*Heb.*)	...	...	...	...	K.T.	...	*	
*Cytherea incrassata (*Sow.*).........	*	*	*	*	K.T.	*	*	
—— turgescens (*Ed. MS.*).........	...	...	...	...	...	*	*	
—— tumida (*Ed. MS.*)	...	...	...	...	...	...	*	
—— suborbicularis (*Ed. MS.*) ...	*	*	K.T.	*	K.T.	...	*	
*—— subelliptica (*Ed. MS.*)	...	...	...	...	...	...	*	
—— hantoniensis (*Ed. MS.*)......	...	...	...	...	...	...	*	
*—— Solandri (*Sow.*), var. attenuata (*Ed. MS.*)	...	...	...	...	K.T.	...	*	
[*]—— elegans (*Lam.*), var. *b*	...	...	...	...	...	...	*	
*—— Suessonensis (*Desh.*)	...	...	...	...	K.T.			
Carried forward......	51	68	71	54	58	34	79	17

Fossils of Middle Headon series, &c. (continued).

	Middle Headon.							Upper Bagshot.
				Brockenhurst beds.				
	Hordwell.	Headon Hill.	Colwell Bay.	Roydon.	Whitecliff Bay.	Lyndhurst.	Brockenhurst.	Long Mead End.
Brought forward …………	51	68	71	54	58	34	79	17
[*]Psammobia compressa (*Sow.*), var. æstuarina (*Ed. MS.*), and var. arcuata (*Ed. MS.*) ……	*	*	*	*	K.T.	…	*	
—— rudis (*Lam.*)=solida (*Sow.*).	…	*	*	…	…	…	…	*
*Tellina affinis (*Ed. MS.*) ………	…	…	*	K.T.	K.T.			
—— headonensis (*Ed. MS.*) ……	…	*	*					
—— sphenoides (*Ed. MS.*) ……	…	…	*					
Syndosmya colvellensis (*Ed. MS.*)	…	…	*					
Mactra fastigiata (*Ed. MS.*) ……	*	K.T.	*	…	…	…	…	*
—— filosa (*Ed. MS.*) ……………	…	…	*	…	…	…	…	*
*Mya angustata (*Sow.*)=M. producta (*Ed. MS.*) ………………	*	*	*	K.T.	K.T.	…	…	*
*Corbula pisum (*Sow.*)…………	…	…	…	K.T.	K.T.	…	*	
*—— cuspidata (*Sow.*)…………	*	*	*	K.T.	K.T.	*		
—— nitida (*Sow.*) ………………	*	…	…	*				
*Panopæa subeffusa (*Ed. MS.*)……	…	*	*					
—— sulculosa (*Ed. MS.*) ………	…	…	…	*	…	…	*	
*Solen gracilis (*Sow.*) ……………	…	…	…	…	…	…	*	
Corbicula obovata (*Sow.*) ………	…	*	*	…	…	*	*	
Cyrena cycladiformis (*Desh.*)……	*	K.T.	K.T.	…	…	…	…	*
—— pisum (*Desh.*) ………………	*							
*Clavagella coronata (*Desh.*)……	…	…	…	…	…	…	*	
—— Goldfussi (*Phill.*) …………	…	…	…	…	…	…	*	
Fistularia Heyseana (*Phill.*) ……	…	…	…	…	…	…	*	
Saxicava, sp.………………………	…	…	…	…	…	…	*	
Pholas, sp. ………………………	…	…	…	…	…	…	*	
Teredo, sp. ………………………	…	…	…	…	…	…	*	
Serpula, sp. ………………………	…	…	…	…	K.T.			
Pollicipes reflexus (*Sow.*) ………	…	…	*					
*Balanus unguiformis (*Sow.*) ……	…	K.T.	*	…	K.T.	…	*	
Callianassa Baylii (*Woodw.*) ……	…	K.T.	*	K.T.				
Solenastræa cellulosa (*Dunc.*) …	…	…	…	…	K.T.	…	*	
—— Kœneni (*Dunc.*) ……………	…	…	…	…	…	…	*	
—— Reussi (*Dunc.*) ……………	…	…	…	…	…	…	*	
—— gemmans (*Dunc.*) …………	…	…	…	…	…	…	*	
—— Beyrichii (*Dunc.*) …………	…	…	…	…	…	…	*	
—— granulata (*Dunc.*) …………	…	…	…	…	…	…	*	
Balanophyllia granulata (*Dunc.*)..	…	…	…	…	…	…	*	
Dendrophyllia ……………………	…	…	…	…	K.T.			
Lobopsammia granulata (*Dunc.*)..	…	…	…	…	…	…	*	
Litharæa brockenhurstii (*Dunc.*)..	…	…	…	…	K.T.	…	*	
Axopora Michelini (*Dunc.*) ……	…	…	…	…	…	…	*	
Madrepora Solandri (*Defr.*) ……	…	…	…	…	…	…	*	
—— Rœmeri (*Dunc.*) ……………	…	…	…	…	…	…	*	
—— anglica (*Dunc.*) ……………	…	…	…	…	K.T.	…	*	
Totals …………………	58	79	87	62	69	36	104	22

Notes relating to Divergences from Prof. Judd's lists of Fossils, with Observations on the Edwards Collection of Middle-Headon Fossils.

Marginella simplex is not in the Edwards collection as from Barton; this and the following ten species, viz. *Mytilus strigillatus, Borsonia sulcata, Nematura parvula, Trigonocœlia deltoidea, Lucina obesa, L. concava, Cardita oblonga* var., *Cardium obliquum, Scintilla angusta*, and *Panopœa subeffusa*, are given in one list as occurring in Barton beds; and in the other list this range is denied to them.

The range into Barton or Bracklesham beds (as shown by the Edwards collection) has been overlooked in the case of many species (viz. twenty-two) in the lists of Colwell-Bay and Brockenhurst fossils (*op. cit.* pp. 153–156).

Voluta depauperata (Sow.) has been cited in error by Forbes from Colwell Bay; it occurs only in Barton or Bracklesham beds, and is therefore omitted from our list. *V. spinosa* (Lam.), type, occurs in Barton and Bracklesham beds; the form from Brockenhurst and Middle-Headon localities might be recognized as a distinct variety.

V. tereticosta (Ed. MS.) is plainly only a variety of *V. geminata* (Sow.) in which the costæ are a little less spiny; all intermediate degrees occur.

Clavella longæva, var. *egregia* (Beyr.). Von Könen mentions this from Brockenhurst; but we find the absence of ridges as rare as in Barton examples, and therefore omit the varietal name.

Hippocrenes ampla (Sow.) is not in Edw. coll. from Headon Hill or Hordwell; and we consider it does not occur there.

Murex sexdentatus, var. *cinctus* (Ed. MS.), is labelled in Edw. coll. as from Barton; but we suspect this to be in error; it appears to be from Colwell Bay, as in Prof. Judd's lists.

Natica obovata (Sow.) occurs at Bracklesham, as shown by the Edw. coll. *N. grossiuscula* (Ed. MS.) is probably only a variety of *N. Studeri*, as transitions exist between them. *N. dubia* (Ed. MS.) we consider only a large variety of *N. lamellata* (Lam.). *N. epiglottina* (Lam.) is in Edw. coll. labelled as from Hordwell; we found it at Roydon.

Cancellaria elongata (Nyst) is in Edw. coll. from Headon Hill and Hordwell, and *C. muricata* from Hordwell. *C. roydonensis* (Ed. MS.) seems a doubtful species.

Cerithium pyrgotum (Ed. MS.) we consider a Lower-Headon form, and omit it therefore. *C. varians* (Ed. MS.) is in Edw. coll. from Headon Hill. *C. cavatum* (Ed. MS.) may be only a variety of *C. concavum*; both it and *C. speculatum* (Ed. MS.) occur only at Long Mead End, and should be omitted from the list. *C. ventricosum* (Sow.) is in Edw. coll. from Colwell Bay; *C. subventricosum* (Ed. MS.) and *C. deperditum*? (Lam.) in Edw. coll. seem to be worn specimens of *C. ventricosum*; we agree with Prof. Judd in omitting them. *C. marginatum* (Ed. MS.), var. *recentius* (d'Orb.), occurs as in our list; its title to a distinct specific appellation seems doubtful. *C.* (*Vicarya*) *concavum* (Sow.) is in Edw. coll. labelled as from

Colwell Bay. *C. trizonatum* (Morr.) is in Edw. coll. from Hordwell &c.; it would therefore seem to be Lower Headon as well as Upper. *C. subconoideum* (Ed. MS.) seems doubtfully a distinct form. *C. æstuarinum* (Ed. MS.) as from Hordwell, in Edw. coll., is founded on a minute fragment, and we do not insert it. *C. headonense* (Ed. MS.) is in Edw. coll. from Headon Hill; but we do not insert it, as it may be Lower Headon only. *C. pulchrum* (Ed. MS.) is in Edw. coll. as from marine Headon beds of Hordwell. *C. pseudocinctum* (d'Orb.) is in Edw. coll. as from Barton.

Turbonilla plicatella (Ed. MS.) is in Edw. coll. from Roydon only; *T. plicatilis* (Ed. MS.) is there as from Colwell Bay and Barton.

Melania brevicula (Ed. MS.) is in Edw. coll. as from Hordwell and Barton; *M. Woodi* (Ed. MS.) from Hordwell seems a Lower-Headon shell, and is not inserted; the names *M. conica*, *M. polygyra*, *M. minima* (Sow.), we could not find represented in the Edw. coll., and omit them.

Rissoa carinata (Ed. MS.) occurs at Barton, but not the var. *denticulata*, according to the labels in Edw. coll.

Conorbis dormitor (Sol.) and *C. procerus* (Beyr.) occur at Barton, but not the special varieties to which MS. names are attached in the Edw. coll.

Hydrobia polita (Edw.) from Headon Hill is Upper Headon only, and therefore omitted; *H. anceps* (Wood) is in Edw. coll. as from Hordwell, Colwell Bay, Long Mead End, and Barton; *H. Dubuissoni*, var. *rimata* (Ed. MS.) is labelled as from Hordwell marine bed.

Trochus pictus (Ed. MS.) is in Edw. coll. from Hordwell; it is in the Woodwardian museum from near Setley Common, Lymington.

Melanopsis ancillaroides (Desh.) was in Edw. coll. subsequently labelled *M. subfusiformis* (Morr.); the former name may be omitted. *M. subulata* (Sow.) occurs twice in Prof. Judd's list, and with different ranges. *M. subcarinata* (Morr.) is in Edw. coll. as from Bembridge and Hordwell marine bed; at the latter locality it probably came from Lower Headon (freshwater) to judge from the aspect of the shell.

The species of *Adeorbis* in Edw. coll. are founded on single individuals; *A. æstuarina* (Ed. MS.) we could not find.

Orthostoma crenatum (Sow.) is in Edw. coll. from Brockenhurst and Barton.

Tornatella altera (Desh.) is determined from a single individual in bad preservation, and seems to us very doubtful. *T. hinnæformis* (Sandb.) [*sic*] of the Brockenhurst list is the same shell as *Actæon limnæiformis* (Sandb.) of the Headon-Hill list; it is in Edw. coll. as from those two localities. *A. simulatus* is inserted on the faith of our own researches. *A. dactylinus* (Desh.) is in Edw. coll. from Colwell Bay; we have found it there also.

Ringicula ringens (Lam.) occurs only in Barton or lower beds.

Trochita obliqua (Sow.) was described originally as "a small but perfect specimen from Brakenhurst [*sic*], in Sussex; the species is found much larger in the cliff at Barton;" the type was only $\frac{1}{8}$ inch long, and was recognized by Sowerby as occurring at Barton, while at Brockenhurst it would have been found in Bracklesham beds probably; we consider it a young example of *T. infundibuliformis* (Lam.). We do not know why Edwards should have referred Brockenhurst forms to a different species from the common Barton species: we have compared numerous examples both from Brockenhurst and Whitecliff Bay, and consider them identical with Lamarck's species; we therefore rank *T. obliqua* as a synonym.

Nerita æstuarina (Ed. MS.) seems identical with *N. zonula* (S. Wood).

Neritina neritopsidea (Ed. MS.) is from the Upper Headon; we therefore omit it.

Ostrea flabellula (Lam.) is in Edw. coll. labelled as from "Colwell Bay *or* Headon Hill" [*sic*], but in error; the specimen has evidently come from the Barton Clay. *O. ventilabrum* is not in Edw. coll. from Colwell Bay, and it does not occur there; we are not sure that the distinctive differences given by Mr. Searles Wood between this species and *O. flabellula* are constant; we have compared examples of this oyster, so common in the Brockenhurst bed at Whitecliff Bay, with other examples from Barton beds; and some we consider perfectly identical with Barton and Bracklesham forms.

Avicula media (Sow.) is not in Edw. coll. as from Hordwell or Headon Hill, but from Long Mead End, *i. e.* probably from the Beacon Bunny (Barton) beds.

Dreissena Brardii (Fauj.) is in Edw. coll. from Hamstead and Hordwell (Long Mead End), ranging thus through all the freshwater series. It occurs in social groups. We found a single derived specimen just above the Lower-Headon boundary at Whitecliff Bay.

Anomia tenuistriata (Desh.) is in Edw. coll. labelled as from Barton, Brockenhurst, and Hordwell; if the Brockenhurst example is to be identified with *A. Alcestiana* (Nyst), probably the Barton ones are so also. We follow Edwards in considering them all one species.

Mytilus strigillatus (Wood) in Edw. coll. is only from Barton beds; we therefore omit it. *M. affinis* is abundant at Colwell Bay, and ranges up from Barton beds.

Nucula similis (Sow.) is in Edw. coll. only from Barton beds; we found one imperfect specimen, however, at White Cliff Bay in the Brockenhurst bed. *N. lissa* (S. Wood) is said by Mr. Wood to occur at Brockenhurst; but it is not in Edw. coll. as from there; the Hordwell examples are possibly from the Upper Bagshot Sands.

Arca appendiculata (Sow.) and *A. lævigata* (Caill.) are in Edw. coll. as from Barton and Bracklesham beds.

Cardita deltoidea (Sow.) is not in Edw. coll. from Colwell Bay; and we doubt the fact of its occurring there.

Lucina Menardi (Desh.), as so determined, is not in Edw. coll. *L. gibbosula* (Lam.) and *L. pratensis* (Ed. MS.), in Edw. coll. as from Long Mead End, are not from Headon beds; we therefore omit them. *L. obesa* (Ed. MS.) and *L. inflata* (Ed. MS.) are in Edw. coll. as from Barton beds; the former is not distinguishable from those labelled *L. concava*; indeed Edwards admitted it as doubtfully distinct.

Diplodonta obesa (Ed. MS.) exists in Edw. coll. from Barton and Bracklesham beds. *D. dilatata* (Sow.), determined as such, is not in Edw. coll.; Dixon cites it from Bracklesham.

Strigilla colvellensis (Ed. MS.) we found to be not unfrequent at Headon Hill. *S. pulchella* (Ag.) is in Edw. coll. determined from a single imperfect valve: it is impossible to say whether it is a second species; and we therefore omit it.

Cardium Edwardsi (Desh.) is not in Edw. coll. from Brockenhurst; it is a Bracklesham shell.

Cytherea suborbicularis (Ed. MS.) we found at Colwell Bay and also in the Brockenhurst zone at Whitecliff Bay. *C. suessonensis* (Desh.): under this name we find in Edw. coll. Barton and Lower-Eocene shells usually referred to *C. tenuistriata* (Sow.); we have it from the Brockenhurst zone in Whitecliff Bay. *C. partimsulcata* (Ed. MS.) is from Long Mead End only; we therefore omit it.

Cyprina scutellaria (Desh.) is solely from Lower-Eocene localities. *C. Nysti* (Héb.) is the only species from Brockenhurst in Edw. coll.; we have it from Whitecliff Bay.

Psammobia compressa (Sow.) is in Edw. coll. from Barton; the var. *arcuata* (MS.) is from Roydon and Brockenhurst; and var. *æstuarina* (MS.) is, according to the labels, from Hordwell, Colwell Bay, and Roydon. We have compared these examples, and cannot see any valid differences; we consider them all one species.

Sanguinolaria Hollowaysii (Sow.) is not in Edw. coll. from Lyndhurst, but is a Bracklesham shell. The Geological Survey cite it in error from Middle Headon beds of Whitecliff Bay.

Tellina corbuloides (Ed. MS.) in Edw. coll., from Colwell Bay, is a crushed specimen, undeterminable, but probably not the Hamstead species; we omit it. *T. ambigua* (Sow.) is in Edw. coll. labelled as from Hordwell, but is probably not from Middle Headon beds, although Forbes cites it from Colwell Bay. *T. reflexa* (Edw.) is a Bracklesham shell, and does not occur above the Upper Bagshot of Long Mead End. *T. headonensis* (Edw.) is in Edw. coll. from Headon Hill and Colwell Bay. *T. sphenoides* (Edw.) is from Colwell Bay. *T. affinis* (Ed. MS.) is in Edw. coll. from Brockenhurst and Barton; we found it also at Whitecliff Bay.

Syndosmya colvellensis (Ed. MS.) seems founded on a single minute valve.

Scintilla angusta (Ed. MS.) is from Colwell Bay, Hordwell, and Barton beds.

Mactra fastigiata (Ed. MS.) which occurs abundantly at Headon Hill, is from Hordwell in Edw. coll. *M. filosa* (Ed. MS.) from Colwell Bay and Long Mead End (Upper Bagshot) we are unable to consider a separate form, so rank it as a synonym.

Solen gracilis (Sow.) is in Edw. coll. from Brockenhurst and Barton beds.

Mya angustata (Sow.) was originally found by Prof. Sedgwick at Colwell Bay; Edwards has an apparently identical shell which he at first identified with Sowerby's species, but subseqnently altered to *M. bartonensis* (Ed. MS.); we cannot, however, see any distinction between these and *M. producta* (Ed. MS.) from Colwell Bay; we consider them all one species. Mr. Searles Wood doubts the Hamstead form *M. minor*, Forbes, being a distinct species either.

Corbula pisum (Sow.) is not in Edw. coll. from Headon Hill or Hordwell; and we doubt its occurrence there; it is, however, fairly abundant in the Brockenhurst zone of Whitecliff Bay. *C. nitida* (Sow.) is in Edw. coll. from Roydon and Long Mead End; it was originally described from Prof. Sedgwick's specimens brought from Middle Headon beds. *C. fortisulcata* (Ed. MS.) we consider merely a variety of *C. pisum*; we omit it, since it comes from Long Mead End, probably from Barton beds. *C. ficus* was found at Brockenhurst by one of the authors, and is now in the Woodwardian Museum.

Panopæa corrugata (Sow.) is, according to the Edw. coll., only a Barton and Bracklesham shell; but quite possibly *P. subeffusa* (Ed. MS.) is not really separable from this species; in either case one of the names must be omitted.

Cyrena subregularis (Ed. MS.) seems to pass into *C. obovata* (Sow.). *C. deperdita* (Lam.) is in Edw. coll. from Headon Hill and Barton; it is probably from the Lower Headon. *C. arenaria* (Forbes) in Edw. coll. is scarcely separable from the preceding; it is from Headon Hill and Hordwell, but apparently from Lower Headon. Mr. Searles Wood figures a different form as Forbes's species. *C. gibbosula* (Morr.) is scarcely a distinct form. *C. æstuarina*, *C. altirupestris*, *C. obliquata*, MS. names in Edw. coll., are not inserted; they may probably be Lower-Headon shells.

Balanus unguiformis (Sow.) we found as frequent at Headon Hill as at Colwell Bay.

Pollicipes reflexus (Sow.) is cited by Forbes from Colwell Bay.

Callianassa Baylii (H. Woodw.) we have from all the zones of the Middle Headon.

EXPLANATION OF PLATE V.

The figure represents the coast-section from Headon Hill east of Heatherwood Point to Cliff End, Colwell Bay; it passes inland at Warden Point to avoid the projecting promontory. An attempt is made to represent where beds may be seen *in situ*, and where they are concealed by fallen material. Notwithstanding that the vertical scale is more than double the horizontal, it is impossible to show much detail; and for this reference is to be made to the accompanying vertical sections (pp. 91, 98, and 103).

The bends of the coast-line are approximately indicated by the compass-bearings given.

Discussion.

The President remarked that the paper was one of great importance. The question at issue was one sharply defined but difficult to come to a conclusion upon without visiting the sections.

Rev. O. Fisher said he had visited the locality with Mr. Tawney's paper and sections in manuscript, and that he agreed with the authors' conclusions. He thought the error on the part of Prof. Judd might have proceeded from the fact that at the N.E. corner of Headon Hill the Middle-Headon fossils were found by the sea-shore; these, however, were not truly *in situ*, but had been brought down by a slip; this he thought possibly the key to the erroneous interpretation. In confirmation of the view that the Colwell-Bay and Headon Venus-beds are one stratum, he had found it with its fossils in Totland brick-field, near the Hotel, exactly where it should occur to connect the disjoined portions. He had worked personally at the Brockenhurst locality at Whitley Ridge, and had identified the bed at the base of the Middle Headon in Whitecliff Bay. Consequently, if the Brockenhurst bed is to be called Oligocene, the Middle Headon can no longer be called Eocene.

Prof. Judd said that the paper rested largely on assumptions. His method of work in the field and in the museum had been made a matter of assumption. He had not hastily arrived at his conclusions, but for twenty years he had worked on these British beds, and for twelve years had studied their continental equivalents and collections of fossils made from them. The series of Eocene and Oligocene strata in Western Europe is perfectly clear; but when we come to Britain a difficulty has always existed. This confusion was removed by distinguishing the zone of *C. concavum* from the Brockenhurst series. The authors' sections were supposed to support those of the Survey; he thought on examination they would not do so. The mistake had really originated from using *Cytherea incrassata* to fix the so-called "Venus-bed" of fossil-collectors—the fact being that that shell has a wide range, and there is more than one "Venus-bed." In asserting that the different "Venus-beds" are upon the same horizon the authors begged the whole question. This autumn he again visited the island, and found that an excavation had been opened by the authors in a Venus-bed in Totland Bay, but in one quite different from that in Colwell Bay. Had the authors searched the Headon cliff they might have found other Venus-beds. The authors had confirmed his own conclusion that the Headon-Hill sands do not occur in Totland Bay; and this is fatal to their reading of the section. As regards the palæontological evidence, he thought that the method of comparison of most abundant fossils was often misleading, as might be shown in the case of the Cornbrash and Ragstone of the Lower Oolite. The authors say that the Brockenhurst bed is not above but below the Venus-bed. Now the former is the equivalent of the Tongrian beds of Belgium; and foreign geologists all regard the zone of *C. concavum* as the top of the Bartonian—that is, of the Eocene. Hence the result of their interpretation of the section was to place beds with an Upper-Eocene fauna *above* those containing a Lower-Oligocene fauna.

Mr. Starkie Gardner said he had always thought that in the particular section under discussion there was only one Venus-bed: the section of Headon Hill till last year had been fairly clear; and he had never seen more himself. He thought "Upper Eocene" and "Oligocene" equivalent terms, and the question, which should remain in use? one of priority.

Mr. Whitaker said that cliff-sections in soft beds were apt to vary from time to time, so that observers who saw them under different conditions of exposure were likely to differ in interpreting them. The examination of other parts of the island, and especially the mapping of limestones or other well-marked beds, might partly help to settle the question in dispute. Perhaps the Geological Survey map had been constructed rather too much on theoretical grounds.

The President said that on the one hand we had the minute measurements of Messrs. Keeping and Tawney, and, on the other, the wider views of Prof. Judd. At any rate these views were now on both sides well laid before the Society; and the question, although a difficult one, as he had himself found in working over the ground 25 years since with Dr. Wright, would be now carefully examined by many others.

Mr. Tawney said that he thought Von Könen, in 1864, had rightly correlated the German and English beds. As for Mr. Whitaker's remarks, he thought a person who was puzzled by a cliff-section would make but little of a drift-covered country where no sections were to be seen. He still denied what Prof. Judd had said about there being more than one marine series. The *Cerithium concavum* zone of Prof. Hébert at Hordwell did not occupy the position attributed to this zone by Prof. Judd in Headon Hill. He maintained that there was but one Venus-bed. The 6-inch *Ostrea vectensis* bed in the Bembridge beds could not be confused with the Middle-Headon Venus-bed.

10. *On two new* Crinoids *from the* Upper Chalk *of* Southern Sweden. By P. Herbert Carpenter, Esq., M.A., Assistant Master at Eton College. Communicated by Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S. (Read February 2, 1881.)

[Plate VI.]

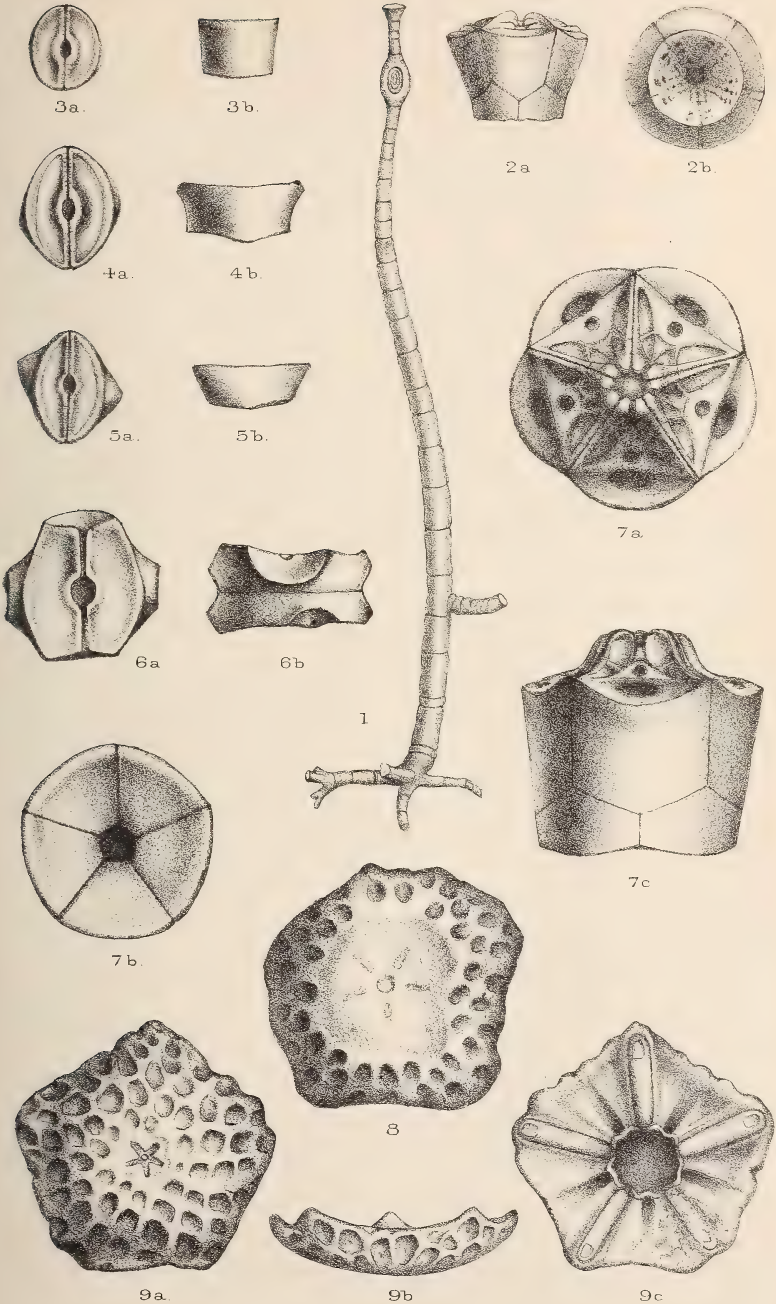
The large work* of Prof. Geinitz on the fossils from the valley of the Elbe in Saxony contains a description of a small stalked Crinoid from the "Plänerkalk" of Strehlen that has long been known to contain stem-joints of the type to which d'Orbigny gave the name *Bourgueticrinus*†. Although no calyx was ever met with, the characteristic stem-joints were supposed to be sufficiently indicative of the presence of the common *B. ellipticus*. Some ten years ago, however, a singularly perfect specimen was discovered, consisting of a complete stem with radicular cirrhi, and a calyx on the top of it (Pl. VI. fig. 1). But this calyx (fig. 2) proved to be totally different in its characters from those of the species of *Bourgueticrinus* described by d'Orbigny. In *B. ellipticus* the calyx is widest round the basal circlet, and tapers gradually downwards into the stem, while the outer surface of the radials has a considerable slant from above downwards and *outwards*. In d'Orbigny's other species, *B. æqualis*, both radials and basals, especially the latter, are relatively narrower and higher, and the whole calyx, together with the top stem-joint, is almost uniformly cylindrical; but in each case the top stem-joint is very large and relatively higher than that of any *Apiocrinus*, while in *B. ellipticus* it widens considerably from below upwards. Its height may be as much as or more than that of the basal and radial circlets together; and the joints immediately below it gradually diminish in width until they resemble the ordinary stem-joints.

In the Strehlen fossil‡, however, the calyx is widest at its upper end, around the upper and outer edges of the radials, so that its diameter diminishes gradually from above downwards (Pl. VI. fig. 2*a*). The broad external faces of the radials slope downwards and *inwards*; and the basal circlet narrows still more, so that the diameter of its lower face is less than two thirds that of the upper surface of the radials (fig. 2*b*). But the top stem-joint, on which the calyx rests, only expands a little from its lower to its upper margin, and its increase in thickness over the one below it is far less marked

* "Das Elbthalgebirge in Sachsen," Palæontographica, Band xx. Theil 2, pp. 18, 19.

† Histoire naturelle générale et particulière des Crinoïdes vivans et fossiles (Paris, 1840), pp. 95, 96.

‡ Thanks to the kindness of Prof. Geinitz, who has made a second examination of this specimen, I am enabled to give a slightly more accurate figure of it than that published by him in the 'Elbthalgebirge' (Taf. vi. fig. 9 *a*). In the older figure only two joints are represented between the calyx and the enlargement on the stem. In that given here three joints are shown instead of two, this later interpretation of the markings on the upper part of the stem being considered by Prof. Geinitz to be the more accurate one.



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SWEDISH CRETACEOUS CRINOIDS.

than is the case in *Bourgueticrinus*. Both it and the joints immediately below it are decidedly smaller than those forming the lower part of the stem, which is just the reverse of what we find in *Bourgueticrinus*.

Prof. Geinitz was unable therefore to refer this specimen to *Bourgueticrinus*, despite the resemblance of its stem-joints to those of that type; but he supposed it to belong to the genus *Antedon* on account of the resemblance of its calyx to that of *Ant. Sarsii*, as represented by M. Sars in his well-known 'Mémoires pour servir à la connaissance des Crinoïdes vivants.' In the specimens figured by Sars*, "the upper end of the stem is not thickened, and the calyx widens from its base to the upper end of the first radial," just as in the fossil from Strehlen (Geinitz †). This resemblance is but an imperfect one, however; for Sars's specimens were merely the stalked larvæ of *Ant. Sarsii*, not more than an inch long. In the later stages of these larvæ ‡ the uppermost stem-joint or future centro-dorsal piece of the mature and free *Antedon* not only becomes considerably enlarged, so as entirely to conceal the basals, but it also bears cirrhi. This, however, is not the case with the corresponding joint of the Strehlen fossil.

Prof. Lundgren § has already pointed out that this specimen is too completely developed to be a larval *Antedon* like those figured by Sars; but neither he nor any other palæontologist has referred it to any definite position among the Crinoids.

The "Mucronatenkreide" (= Upper Chalk) of Köpinge, near Ystad, in Southern Sweden, contains a quantity of stem-joints (Pl. VI. figs. 3–6) which have been considered as belonging to *Bourgueticrinus ellipticus*, though no calyx of this species has yet been found associated with them. Some years ago, however, a singular calyx was met with (Pl. VI. fig. 7), which was presented to the Geological Museum of the University of Lund by Herr Rector Bruzelius, of Ystad, into whose hands it had come. Its discovery was announced in the 'Neues Jahrbuch für Mineralogie' by Prof. Lundgren, who at once recognized its resemblance to the so-called *Antedon Fischeri* of Geinitz (Pl. VI. fig. 2). It is, however, considerably larger and much less conical; but it has even less resemblance than the Strehlen fossil has to the cylindrical *Bourgueticrinus æqualis*. During my recent visit to Lund for the purpose of examining the *Comatulæ* of the Retzian collection, Prof. Lundgren showed me this fossil, and was kind enough to intrust it to me for description. For this and for many other acts of kindness I offer him my heartiest thanks.

For these two fossils, so similar in their general characters though differing in points of detail, I believe that not only a new genus, but also a new family must be established. I propose to call the genus *Mesocrinus*; for while allied to *Bourgueticrinus* in the characters of its stem-joints, it is quite as closely allied to the Pentacrinidæ in the characters of its calyx. The only real resemblance

* *Op. cit.* pls. v., vi. † *Op. cit.* p. 18. ‡ *Op. cit.* pl. vi. fig. 24.
§ Neues Jahrbuch für Mineralogie, 1876, pp. 180–182.

to the Apiocrinidæ is in the nature of the faces of the stem-joints, which resemble those of *Bourgueticrinus* and *Rhizocrinus*. But similar joints occur in the larval *Antedon* and in *Platycrinus* *; so that this resemblance does not go for much, especially when it is remembered that d'Orbigny speaks of the articular faces of the stem-joints in the Apiocrinidæ as being most frequently marked with radiating striæ †.

On the other hand, *Mesocrinus* differs from the Apiocrinidæ as defined by d'Orbigny and by Zittel ‡, in the presence of verticils of cirrhi on the stem, and in the small size of its upper joints. Further, the central funnel of the calyx (Pl. VI. fig. 7*a*) is small, not wide and patent; while the articular faces of the radials are large, and not separated or barely in contact, but meet one another along the whole length of their sides, and bear distinct fossæ for the attachment of muscles and ligaments. All these characters are more or less distinctive of the type of the Pentacrinidæ; but *Mesocrinus* cannot be referred to that family, as it lacks the petaloid markings on the faces of the stem-joints.

Mesocrinus, n. g.

Calyx more or less conical, composed of five basals forming a complete ring, and five radials with high articular faces which bear distinct muscular and ligament-fossæ, and are in contact for the whole length of their sides. Upper stem-joints the smallest. Lower ones with elliptical faces, the long axes of which are occupied by articular ridges. The planes of these ridges on the two faces of each joint are more or less inclined to one another. The joints may bear single cirrhi, or two may combine to form a node for a verticil of two cirrhi. Radicular cirrhi at the base of the stem.

Mesocrinus suedicus, n. sp. (Plate VI. fig. 7.)

The lower part of the calyx is formed by five pentagonal basals, which are in complete contact laterally, so as entirely to cut off the radials from the top stem-joint. The lower surface of the basal pentagon is very concave, with a large central perforation; but it is quite simple and devoid of any kind of ornamentation (Pl. VI. fig. 7*b*). The radials have very high outer surfaces (nearly twice as high as the basals), which slope very slightly upwards and outwards. Their articular faces are also rather high and trapezoidal, with large muscle-plates standing up around the central funnel. The thickened edges of the two muscle-plates on each radial are separated by a slight intermuscular notch. The transverse ridge expands into a large articular surface perforated by the opening of the central canal, to which it forms a thick rim on all sides. From this surface short ridges proceed upwards and outwards, separating the large muscle-fossæ from the small ligament-fossæ. The dorsal fossa for the elastic ligament is relatively small, being represented by little more

* A Natural History of the Crinoidea (Bristol, 1821), pp. 34, 75.

† *Op. cit.* p. 1.

‡ Handbuch der Paläontologie, Band i. p. 388.

than the pit beneath the transverse articular ridge, around which is a simple smooth surface.

Size. Height 5 millim., greatest diameter 5 mm., least diameter 4 mm., greatest height of basals 1·5 mm., least height 1 mm., width 3 mm.

As already pointed out by Prof. Lundgren, the stem-joints which occur associated with this calyx are referable to three principal types. It is, of course, possible that they belong to another species altogether; but, like Prof. Lundgren, I am inclined to refer both calyx and stem-joints to one and the same species. The question cannot, of course, be decided until the Swedish collectors are fortunate enough to meet with a perfect specimen.

Type 1. Thin circular disks, about 3 millim. in diameter, with faces perforated in the centre, but without markings of any kind. They probably belong to the upper part of the stem immediately beneath the calyx. Both in some forms of *Bourgueticrinus** and in *Rhizocrinus* the upper stem-joints have simple faces without any of the characteristic sculpture which occurs lower down the stem. The thin penultimate joint of *Mesocrinus Fischeri* (Pl. VI. fig. 1) would seem to have been of this nature; and one can readily imagine that in the larger *M. suedicus* the number of such simple stem-joints was larger, as is actually the case in *Bourgueticrinus.*

Type 2. The joints of this, the commonest type (Pl. VI. fig. 3.), are higher, with oval articular faces, the long axes of which are occupied by transverse ridges. The planes of the ridges at the two ends of each joint are inclined to one another at angles of from 60° to nearly 90°; and the centre of each ridge expands considerably around the opening of the central canal into a well-marked articular surface. A median groove extends along each half of the ridge from the central opening towards the margin of the joint-face; and short shallow branches proceed from it on each side so as to cut out the upper portion of the ridge into a double row of small teeth.

According to Prof. Lundgren these joints vary in size from 3 to 8 millim. in diameter, usually 5 or 6 millim.; and their height is about equal to their diameter.

Type 3 (Pl. VI. figs. 4–6). Wider but lower joints, the oval faces of which are much more pointed than in those of type 2. They differ very much in the proportion of height to diameter. In the thicker ones (fig. 4) the expansion of the transverse ridge around the opening of the central canal is very distinct, and there is a crescentic pit on either side of it. But these features are much less marked in the thinner joints, the faces of which are flatter (fig. 5), while the transverse ridges scarcely expand at all around the central canal. Some of these joints bear portions of the cirrhus-sockets, as already pointed out by Prof. Lundgren. As in some species of *Pentacrinus,*

* This is certainly the case in several specimens that I have examined, some of which, contained in the University collection at Berlin, were kindly shown to me by Prof. Beyrich. On the other hand, Quenstedt figures a top stem-joint of *B. ellipticus* with a distinct transverse ridge and articular facet on its under surface (Petrefactenkunde Deutschlands, Band iv. tab. 104. fig. 76).

two joints contribute to the formation of a socket, and the sockets are at the ends of the long axes of the two apposed faces, so that there were two cirrhi at each node, and at least three nodes in immediate succession (fig. 6). The two grooves in the respective transverse ridges form by their apposition a canal which lodged the vessels proceeding to the two cirrhi from the central vascular axis of the stem, and opened at the bottom of each cirrhus-socket *.

In the absence of complete specimens of *Mesocrinus suedicus* it is, of course, impossible to determine where these nodes or, rather, groups of nodes occured in the stem, or even whether a stem of this character was associated with the calyx under description. I suspect that the verticils of cirrhi were limited to the wide lower part of the stem; but it is not possible to form any opinion as to whether they were simple cirrhi like those of *Pentacrinus*, or irregularly branched radicular structures like those on the lower stem-joints of *Rhizocrinus lofotensis*.

Failing direct evidence to the contrary, it certainly seems to me most probable that the calyx and stem-joints from Köpinge all belong to one species, which would then differ from *Mesocrinus Fischeri* in other characters than those of the calyx; for the lower joints of *M. Fischeri* (Pl. VI. fig. 1) are all much longer than wide, as in *Rhizocrinus*, *Bathycrinus*, and the larval *Antedon*, and they rarely bore cirrhi (Pl. VI. fig. 1). In this latter respect *M. suedicus* must have been related to *M. Fischeri* much in the same way as *Rhizocrinus lofotensis* with abundant radicular cirrhi on the lower part of its stem is related to *R. Rawsonii* † which had " very few radicular cirrhi."

The wide lower stem-joints of *M. suedicus* (Pl. VI. figs. 4–6) have much less resemblance to the corresponding joints of *M. Fischeri* than to those of *Bourgueticrinus ellipticus*, as represented by d'Orbigny; and they further resemble these last in having the transverse ridge continuous across the articular face. In *B. constrictus*, however, the ridge is interrupted in the centre, and the more or less marked excavations in the lateral portions of the joint-face are connected with one another round the central canal, very much in the same manner as the two cornua of the grey matter unite around the central canal of the spinal cord ‡. This feature is also distinctive of *Rhizocrinus* and of the *Antedon*-larva §; and in both of these types the transverse ridge is cut up into a double row of minute teeth. So far as I know, this character has never been described in any species of *Bourgueticrinus*; and Geinitz neither describes nor figures it in *Mesocrinus Fischeri*, though (as mentioned above) it occurs in *M. suedicus*.

* Quenstedt (*op. cit.* p. 368) has described cirrhus-sockets on stem-joints from the White Chalk of Rügen, and has remarked that the grooves in the transverse ridges of these nodal joints are often very distinct; but there seem to have been more than two cirrhi at each node (tab. 104, fig. 63).

† "Zoological results of the Hassler Expedition. I. Echini, Crinoids, and Corals," Illustr. Catalog. Mus. Comp. Zool. at Harvard College, no. viii. p. 27.

‡ This seems to be also the case in the so-called *B. ellipticus* from the Eocene of Traunstein (Quenstedt, *op. cit.* iv. tab. 104. fig. 82).

§ Sars, 'Crinoïdes vivants,' pp. 5, 6, pl. ii. fig. 27, and pl. vi. fig. 17.

One of the stem-joints of *M. Fischeri* which is figured by Geinitz is very singular. There is a thick articular rim around the opening of the central canal of the oval-oblong face, as in the lower stem-joints of *M. suedicus*; but the ridge proceeding from this to either end of the oval is Y-shaped and not simple. Some of the stem-joints of *B. ellipticus* and also of *Platycrinus lævis* which were figured by Miller * present very similar characters; but I have not found them in any of the joints of *M. suedicus.*

The genus *Bourgueticrinus* is rather in confusion just at present, all those stem-joints occurring in the Mesozoic rocks being referred to it that have elliptical articular faces with transverse ridges upon them, which are in different planes at the two ends of each joint; and we are unable to classify these joints properly in the absence of sufficiently perfect specimens of whole individuals.

In any case, however, the so-called *Antedon Fischeri* and its Swedish ally have stem-joints closely approximating to the *Bourgueticrinus* type (Pl. VI. figs. 3–6). Nevertheless the calyx is quite different (Pl. VI. figs. 2 & 7). Seen from the side it has a certain resemblance to some forms of *Millericrinus Münsterianus*, d'Orb., and of *M. Nodotianus*, d'Orb. But this resemblance disappears altogether when the upper surface of the calyx is examined; for the central funnel of *Millericrinus* is very large, and the articular faces of the radials which surround it are wide and low, barely meeting laterally; while *Mesocrinus* has quite a narrow central funnel (fig. 7, *a*) and relatively high articular faces, which diminish considerably in width towards their upper ends, but are in contact for the whole length of their sides.

On the whole the calyx most resembles that of a *Pentacrinus*, or rather of that section of the genus with a closed basal circlet, which is referred by de Loriol † to *Cainocrinus*. Had I either calyx alone before me, I should certainly refer it to *Pentacrinus*, among the recent species of which there is a considerable variation in the proportions of the different parts of the calyx ‡. In *Cainocrinus*, *Millericrinus*, *Bourgueticrinus* §, and *Rhizocrinus*, the composition of the calyx is the same. In all these genera there is a closed circlet of five basals, on which the five radials rest, just as they do in *Mesocrinus*. But there are considerable differences among these five types in the nature of the articular faces of the radials. In *Millericrinus* these faces are very wide and low, and are nearly or quite separated laterally, while the fossæ for the muscles and interarticular ligaments are usually but slightly developed ||. In *Bourgueticrinus* the articular

* *Op. cit.* pp. 34, 75.

† 'Monographie des Crinoïdes fossiles de la Suisse,' Geneva, 1877–1879, p. 111. See also "On the Genus *Solanocrinus*, Goldfuss, and its Relation to Recent Comatulæ," Journ. Linn. Soc., Zool. vol. xv.

‡ Compare figs. 21 and 23 on pl. xi. of Journ. Linn. Soc. Zool. vol. xv., with fig. 3 on pl. vi. of the Popular Science Review, new ser. vol. iv.

§ In some specimens of "*B. ellipticus*" in the national collection at South Kensington the basals appear externally as small triangular pieces which are not in contact laterally.

|| According to de Loriol, *Millericrinus* differs from *Apiocrinus* in the presence of an articular facet on the first radials. In the latter genus "leur surface

faces are much reduced and quite insignificant, while in *Rhizocrinus* they are wide, low, and separate, and more like those of *Millericrinus*, enclosing a wide central funnel.

In both species of *Mesocrinus*, however, and especially in *M. suedicus*, the articular faces are much higher relatively to their width, are in contact for the whole length of their sides (figs. 2 *a*, 7 *a*), and have distinct muscle-plates, which stand up around the opening of the small central funnel. These are largest and best developed in *M. suedicus*, but are distinctly recognizable in Geinitz's figure of *M. Fischeri*.

These features are eminently characteristic of the Pentacrinidæ and Comatulidæ, though I have seen no calyx of *Pentacrinus* which could be said to be precisely like that of *Mesocrinus*. But then no two *Pentacrinus*-calices that I have seen are precisely like one another; for they differ very much among themselves, not only in the relative development of the basals, but also in the shape and proportions of the outer surface of the radials and of their articular faces. At the same time it must be remembered that we are only just beginning to become acquainted with these modifications; for neither species nor individuals of living forms are at all abundant in collections, much less are they available for anatomical investigation. The calyx of *Mesocrinus Fischeri* (fig. 2) finds its nearest ally in that of *P. Wyville-Thomsoni**. It is in a side view that the resemblance is most evident, the chief point of difference being the greater height of the radials and of their articular faces in *Mesocrinus*. These features are more marked, however, in *P. asteria*†; but in this species the basals are small, and do not meet laterally as they do in *Mesocrinus*. Except in this point the calyx

supérieure ne servait pas de point d'attache" (*loc. cit.* p. 32). I regret that I cannot altogether agree with this opinion of the distinguished Swiss palæontologist, who must have been unfortunate in some of the specimens he examined. The large concave surface in which the second radials of *Apiocrinus* rest is sometimes an expansion of what in recent Crinoids is the dorsal fossa lodging the elastic ligament. This is well shown in de Loriol's own figures of the ventral aspect of the first radials of *A. Meriani* (pl. ii. figs. 4*a*, 5*a*), and also in d'Orbigny's figure of *A. Murchisonianus* (pl. vi. fig. 7). The central end of this large fossa is bounded by the transverse articular ridge pierced by the opening of the central canal; and rising up from this ridge so as to form a part of the rim of the central funnel are larger or smaller plates for the muscle- and ligament-fossæ. In some specimens of *Apiocrinus* in the national collection these fossæ are relatively large and are separated by a well-marked ridge; but in most species they are greatly reduced in size, as is also frequently the case in *Millericrinus*. In the latter genus the dorsal fossa never reaches the enormous size that it does in *Apiocrinus*, and, though it is sometimes relatively large (as in some *Comatulæ*), it is occasionally comparatively small.

I am not prepared to say, however, that no *Apiocrinus* had the first and second radials united otherwise than by muscles and ligaments. They must, in some cases, have been joined by a syzygy, *e.g. Ap. Parkinsonii* (d'Orbigny, pl. v. fig. 6); but such cases are very anomalous; for in the other Articulate Crinoids syzygial union, though common enough between the second and third radials, never takes place between the first and second. Even in *Marsupites* there is a distinct articular facet on the first radials.

* Journ. Linn. Soc., Zool. vol. xv. pl. xi. fig. 23.

† Journ. Linn. Soc., Zool. vol. xv. pl. xi. fig. 21.

of *P. asteria* is not unlike that of *M. suedicus* (Pl. VI. fig. 7), which has much more resemblance to it than to the calyx of any species of *Millericrinus*.

Despite the resemblance of their calices to the *Pentacrinus*-type, the so-called *Antedon Fischeri* and its Swedish ally obviously belong to another genus than *Pentacrinus*. They lack the typical stem of this genus, with its verticils of cirrhi from the top downwards and the petaloid markings on the joint-faces. Neither does *Mesocrinus* possess the typical stem of *Apiocrinus* or *Millericrinus*; but while chiefly resembling *Bourgueticrinus* in the character of its stem, it differs from that genus and approaches *Rhizocrinus* in the comparatively small size of its upper stem-joints; and it especially resembles *R. Rawsonii* in the relatively slight increase in the diameter of its calyx from below upwards. In neither case does the calyx pass gradually downwards into the thickened upper end of the stem, as it does in the typical Apiocrinidæ and in *Bourgueticrinus*, to which, in other respects, *Mesocrinus* has a considerable resemblance.

The similarity of the articular faces of the stem-joints of the young *Antedon Sarsii* to those of *Rhizocrinus*, and the imperfect radicular processes that proceed from the lower part of its stem, are characters which connect the Comatulidæ with the Apiocrinidæ. The Pentacrinidæ, however, are sharply marked off from the latter family by the striking differences in the character of the stem. It is therefore of no small morphological interest to find a type in which the characters of a *Pentacrinus*-calyx are combined with those of a *Bourgueticrinus*-stem. It is quite possible that some of the stem-joints now referred to *Bourgueticrinus* may belong to other intermediate forms, the calices of which are still unknown to us, as that of *Mesocrinus* was but a few years ago.

Prof. Lundgren has been kind enough also to intrust to me the description of a new *Antedon*, two specimens of which were found by himself and by Mr. J. Chr. Moberg in the Ignaberga Limestone at Balsberg, in the province of Scania, S.W. Sweden.

ANTEDON IMPRESSA, n. sp. (Plate VI. figs. 8, 9.)

Centrodorsal a thin convex pentagonal disk with very indistinct traces of a small five-rayed impression at the dorsal pole. In the larger specimen the dorsal surface is somewhat flattened and tolerably free from cirrhi (fig. 8), but in the smaller and younger specimen there is but a very small cirrhus-free space (fig. 9, *a*). There are about 40–50 sockets arranged in three rather indistinct rows, with occasional traces of a fourth; but they are too much worn to show any structural details.

The ventral surface is entirely obscured by matrix in the larger specimen, and is only partly visible in the smaller one. It is markedly concave; and its angles are somewhat produced upwards and outwards. In the middle line of each radial area is a median groove, the central end of which is deepened and forms a radial pit. The outline of the central opening was probably decagonal; and from its interradial sides there proceed five linear oblong basals, which do not quite reach the circumference. The outer end of each is marked by an oval oblong impression.

Diameter, larger specimen 8 millim., smaller 5 mm.

Height, larger specimen, 2 millim., smaller 1·5 mm.

Remarks. I do not know of any *Comatula*, either recent or fossil, with a centrodorsal at all like that of this species, except *Antedon Tourtiæ*. Schlüter * figures five slight grooves radiating outwards from the radial pits of this last species; but he makes no mention of them in the text. The ventral surface of its centrodorsal is slightly concave, with the angles raised; but this is far less distinctly the case than in *A. impressa*; and the centrodorsal is half as high as it is wide, and bears four vertical rows of cirrhus-sockets, characters which distinguish it sharply from *A. impressa*.

The persistence of the basals in connexion with the centrodorsal rather than with the radials is also interesting. They are probably the original embryonic basals (or orthobasals), as in *A. Lundgreni* and a few other species †. If they were merely basal rays connected with a rosette, some trace would have remained of such a connexion; but I can find none.

EXPLANATION OF PLATE VI.

Fig. 1. *Mesocrinus Fischeri*, Geinitz, sp., natural size. Copied from an amended drawing of the original, kindly lent by Prof. Geinitz.

2. Calyx of *Mesocrinus Fischeri*, enlarged: *a*, side view; *b*, dorsal surface.

3–6. Stem-joints from Köpinge, S. Sweden, probably belonging to *Mesocrinus suedicus*, all × 2: *a*, face views; *b*, side views.

7. Calyx of *Mesocrinus suedicus*, nov. gen. et sp., × 6: *a*, ventral surface; *b*, dorsal surface; *c*, from the side.

8 & 9. Centrodorsals of *Antedon impressa*, n. sp.: fig. 8. Dorsal surface of the larger specimen, × 4; fig. 9. Smaller specimen, × 6: *a*, dorsal surface; *b*, from the side; *c*, ventral surface.

Discussion.

The President expressed his sense of the value of the author's communication, and hoped he would continue his work.

Prof. Duncan expressed the same view.

Prof. Seeley said the variations of *Bourgueticrinus* were very remarkable, both in form and in structure of the calyx. He had never seen one with the structure of that described, but had seen some approaching it. He eulogized the description given by the author, and expected from him important contributions to the knowledge of the Cretaceous Crinoids.

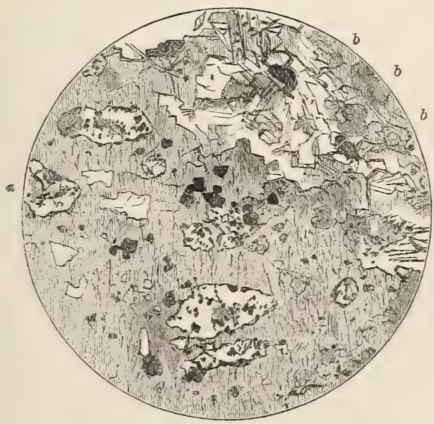
* "Ueber einige astylide Crinoiden," Zeitschr. d. deutsch. geol. Gesellsch. 1878, p. 41, Taf. i. figs. 4–6.

† Quart. Journ. Geol. Soc. 1880, vol. xxxvi. p. 550; Journ. Linn. Soc., Zool. vol. xv. p. 213.

11. *On a* Boulder *of* Hornblende Picrite *near* Pen-y-Carnisiog, Anglesey. By Prof. T. G. Bonney, M.A., F.R.S., Sec. G. S. (Read January 5, 1881.)

Last summer, through the kindness of Professor Rosenbusch, I was able to examine several specimens of picrite in the Geological Museum at Heidelberg, and to study the rock in the field, near the village of Schriesheim, a few miles to the north of that town. In September I was walking with some students along the road which leads out of the village of Pen-y-Carnisiog northwards to Bwlyn (Anglesey), when I observed, in a field on the left, the fractured face of a boulder, in which a number of large crystals resembling augite, glittering in the sunlight, in a dull dark matrix, recalled at once the characteristic aspect of the Schriesheim picrite. The boulder had been broken, apparently rather recently, into three pieces, one much smaller than the other two; and its volume must have been not much less than a cubic yard. In its weathered surface and toughness under the hammer it also resembled the Schriesheim rock. In both, the larger crystals (which are often about two thirds of an inch long) contain a number of dark serpentinous-looking enclosures, giving to the cleavage-faces an interrupted lustre somewhat resembling (except in the absence of a metallic gleam) that of bastite. The Pen-y-Carnisiog rock looks a little more decomposed; but macroscopically the resemblance between my two specimens is so great that one could believe them to have been broken from different parts of the same mass.

Part of a Slice from a Boulder of Hornblende Picrite near Pen-y-Carnisiog, Anglesey. (Magnified 30 diameters.)



a. One of the grains of altered olivine.
b, b, b. Aggregated small crystals of hornblende, probably of secondary origin.

When the Pen-y-Carnisiog rock is examined microscopically, the difference between the two is rather more marked. In it the predominant mineral is undoubtedly hornblende. This occurs under three forms:—(*a*) innumerable small acicular or blade-like crystals, in irregular tufted groups, forming a kind of ground-mass; these vary from a pale green tinge to almost colourless, and are generally very feebly, if at all, dichroic; the comparatively small extinction-angle shows them to be hornblende (actinolite); and there can be no reasonable doubt that they are of secondary origin; (*b*) small crystals, exhibiting often characteristic cleavages and even external forms (combinations of ∞P and $\infty P^c\infty$), green-coloured and strongly dichroic; (*c*) large crystals (those mentioned above as supposed augite), including grains &c. of more than one other mineral, to be presently noticed. Augite occurs not unfrequently in almost colourless grains and crystals, some of which show a characteristic cleavage, and, in one or two cases, the characteristic outline (section of the combination of ∞P, $\infty P^c\infty$, $\infty P^o\infty$). The extinction-angle of the longitudinal sections of these crystals is large, ranging commonly from 30° to 40°. They usually occur interspersed in a dull olive-green serpentinous or chloritic mineral. No olivine can now be recognized with certainty in the slides; but there are a number of irregular grains associated in them with the other minerals, and abundantly included (these being of smaller size) in the large hornblende crystals, which there is every reason to believe are pseudomorphs after the former mineral. Opacite and rounded crystalline grains resembling magnetite abound in these, often clustered together or lining roughly parallel cracks, which remind us of the irregular cleavages of olivine; from these a brown staining often extends inwards for some little distance. The pseudomorphic constituents vary considerably: sometimes, as described above, they are a brownish or yellowish green, of filmy granular structure, acting upon polarized light, but not greatly changing their colour; sometimes they exhibit a finely-speckled aspect, as though aggregates of extremely minute grains or folia of a mineral that acts strongly upon polarized light; sometimes they are aggregated small folia of a mineral resembling talc; and sometimes a clear isotropic, or nearly isotropic, mineral, such as is common in ordinary serpentines. Two or three of the inclusions in the larger hornblende crystals exhibit a radial aggregate structure with the usual black crosses. Though most of the above microlithic products are not the most usual replacements of olivine, I have seen them occasionally in my studies of peridotites, and have no doubt that this mineral was formerly present in the Pen-y-Carnisiog rock (probably a rather ferriferous variety). Magnetite is not uncommon as an inclusion in the larger hornblende crystals; the slide also contains a little altered brown mica, and a few small crystals of apatite.

With regard to the large black crystals already mentioned, although, from their optical properties, one cannot but regard them as a brown hornblende, I doubt much whether this is not due to subsequent paramorphic change, and believe that they were formerly a true augite. The extinction-angles are generally less than 20°; but in one slide are two crystals which, though dichroic, give angles of about 30°. The larger crystals of the Schriesheim picrite agree with augite in their feeble dichroism and general appearance; but the results of several measurements of the extinction-angle are less than 20° in the case of the largest crystal, while in a smaller one they are over 30°; and a very considerable quantity of hornblende, similar to the varieties (*a*) and (*b*), is present in the body of the slide. A little olivine has escaped change; and the structure of the rest is rather more characteristic. Still, except that a mica is decidedly more abundant in the Schriesheim than in the Pen-y-Carnisiog rock, the main difference appears to me to be, that the latter has undergone more alteration than the former, so that it, too, has once been a true picrite.

Another rock is very abundant in boulders in this district of Anglesey, which, at first sight, has some resemblance to the picrite, though less porphyritic in structure. Closer examination, however, shows that felspar is always a constituent of this, though it is often not very conspicuous. I have examined a specimen microscopically, and find it to consist of a green hornblende, an altered felspar, a brown mica more or less changed, apatite, and a chloritic mineral. The hornblende and felspar are rather irregular in external form: the latter is almost wholly replaced by microlithic products; but one or two grains still retain sufficient traces of their original structure to show they have been plagioclastic. It is somewhat singular that a rather similar rock, but with more brown mica and better-preserved felspar, occurs at Schriesheim, within a short distance of the picrite, also intrusive in the granite. This is named a Labrador-diorite by the German petrologists.

The only other instances known to me of the occurrence of picrite in the British Isles are two in Fifeshire, described by Prof. Geikie in his excellent monograph on the Carboniferous Volcanic Rocks of the Firth-of-Forth basin*, and one described by myself†, to which, as I had at that time never examined a typical picrite, and had failed to obtain a very clear notion of the rock from such descriptions as I had seen, I did not venture to attach the name. In this, however, olivine (still very fairly preserved) is the dominant mineral; so that it comes nearer to a normal peridotite. The rock was collected many years ago by Professor Sedgwick, near Penarfynydd, in the Lleyn peninsula; and Mr. E. B. Tawney, who lately visited the locality expressly to search for it *in situ*, failed to find it, and believes that the specimen must have been taken from a boulder. Here also, as described by Mr. Tawney, are olivine-diabases and hornblendic diabases.

I have ventured to draw especial attention to this Anglesey specimen, in the hope that some geologist may succeed in discovering a like rock *in situ*. As the picrite just described is so uncommon and of so marked a character, we might assume with much confi-

* Transact. Roy. Soc. Edinburgh, vol. xxix. p. 437.

† In a paper by Mr. E. B. Tawney, Geol. Mag. Dec. 2, vol. vii. p. 208.

dence (supposing no physical difficulties presented themselves) the Pen-y-Carnisiog boulder to have been derived from that parent rock. This would afford us most valuable evidence as to the direction in which the agent of transport (doubtless ice) had formerly moved. The south side of the Lleyn peninsula, even if the rocks corresponded (which they do not), seems excluded by physical considerations; but I may remark that, though I have examined many boulders in Anglesey, I have failed as yet to identify any of them with rocks from the Lake District or from Scotland, and think that we must look to the mountains of North Wales for the home of those which cannot be found in Anglesey itself.

12. *The* Geology *of* Central Wales. By Walter Keeping, Esq., M.A., F.G.S., Lecturer on Geology in the University of Cambridge. *With an* Appendix *on some new Species of* Cladophora, by Charles Lapworth, Esq., F.G.S. (Read June 23, 1880.)

[Plate VII.]

Contents.

Part I.

The following communication contains some of the results worked out in frequent field-excursions during three years' stay at the University College of Wales, Aberystwyth. In many of these excursions I was accompanied by my students of the College; and to them I am indebted for much help both in the museum and the field*. Our principal field of work was, naturally, within a radius of some fifteen to twenty miles around the town of Aberystwyth; and most of this country we have carefully searched and traversed through and through. The more distant areas to the south of Cader Idris, at Llanbrynmaer, Llandovery, Llandeilo, Cardigan, &c., have also been visited with a view to the determination of the extent and variation of the Cardiganshire rock-groups, and the discovery of their stratigraphical relations to other and better-known geological horizons.

Little has yet been done by geologists to elucidate the structure of this part of Wales: while the most careful labours of our greatest authorities have been devoted to the study of the northern counties and eastern borders of Wales, and also, of late years, to the south in Pembrokeshire, this barren and chaotic area of Mid Wales has been always neglected, and is even now very rarely touched with the geological hammer. For the bibliography of our subject we have therefore but little to say, the most important contributions being:—the work

* In particular, I have received much assistance from my former pupils Mr. T. Roberts, now of St. John's College, and Mr. E. Evans of Sidney College, Cambridge.

of our great leader Sedgwick, published in the Society's Journal in the year 1847 (vol. iii. p. 150); a slight account of the Dol Fan conglomerate, and a description of the Lampeter worm-trails in Murchison's 'Silurian System,' pp. 316, 317; some scattered remarks by Mr. Salter and Sir Roderick Murchison in 'Siluria,' and by the former in the Cambridge 'Catalogue.' The Pont Erwyd district is referred to in Symonds's 'Records of the Rocks,' pp. 132, 133; some Graptolites from Aberystwyth are recorded by Mr. J. Hopkinson, F.G.S., in the 'Journal' of the Quekett Microscopical Club, vol. i. p. 151; and the mineral veins of Cardiganshire are described by Mr. Warington Smyth, M.A., F.R.S., in the 'Memoirs of the Geological Survey,' vol. ii. part 2, p. 485.

The present communication, although worked out in a close network of foot-routes in parts of the district, and cross traverses over the rest, is offered only as a first reconnoissance report, which must be followed by many labours before the structure of this great and complicated district can be thoroughly mastered. Some general order amidst the whirl of contortions, however, is now made clear, such as the general succession of the Aberystwyth, Metalliferous, and Plynlimmon groups, and the great Plynlimmon synclinal. The enormous apparent thicknesses of the rocks are shown to be in part due to a series of inversions; and, further, the interpretation and correlation of the beds are greatly helped forward by discoveries of fossils, mostly Graptolites, in a number of localities, which afford excellent data for comparison with the more distant Scotch and Cumbrian Silurians.

Even Sedgwick's work (1846) was but of a very superficial kind; for he tells us, "I profess not to know well this most contorted and perplexing country." He makes four rock groups, namely the (1) Aberystwyth, (2) Plynlimmon, (3) Upper South-Wales Slate with the Rhyader Slate, and (4) Cambro-Silurian groups, which appear in ascending order from west to east; but he adds, "the sections are singularly contorted, the groups ill defined, and the actual order of superposition obscure." His first group I still maintain under the name of the Aberystwyth grits; but nearly all the remaining rocks in the line of section might, I believe, have been included in his second great series—the Plynlimmon group. On the other hand, I have considered this great Plynlimmon group of Sedgwick under two distinct headings, namely the (inferior) slate series or *Metalliferous-slate group*, and the overlying *Plynlimmon grits*, so that we now have the following succession of deposits:—

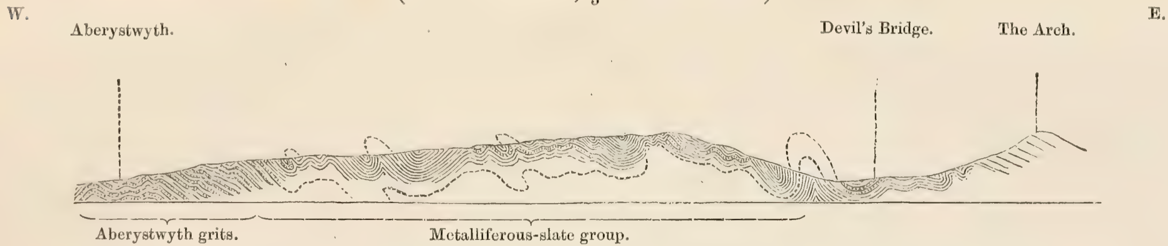
	(3) The Plynlimmon grits, forming a line of high country in the centre of Wales, including Plynlimmon.
Cardiganshire group.	(2) The Metalliferous-slate group, forming a broad zone of contorted country on each side of (3).
	(1) The Aberystwyth grits, best developed between Aberystwyth and Aberayron.

Nos. (1) and (2), being closely bound together by their fossils, are known together as the Cardiganshire group.

For an illustrative section of our area the best I can offer is that from Aberystwyth, through the Devil's Bridge, to the Plynlimmon

Fig. 1.—*Section from Aberystwyth to the Devil's Bridge.*

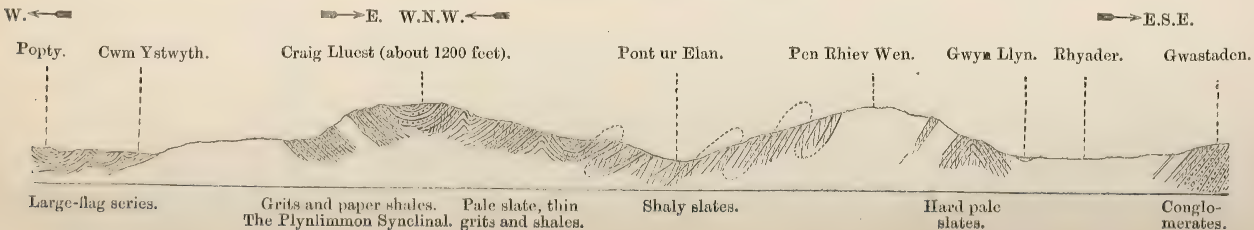
(Horizontal scale, $\frac{1}{3}$ inch to a mile.)



The continuous dotted line indicates the probable course of the Cefn Hendre and the Devil's-Bridge fossil-zone.

Fig. 2.—*Continuation of the Section in fig. 1, from Cwm Ystwyth, through Craig Lluest, to Rhyader and Gwastaden.*

(Horizontal scale, $\frac{1}{3}$ inch to a mile.)



Mountains (figs. 1 & 2). The lowest beds form the cliffs at the coast, while the highest go to form the central mountains. All these rocks are amazingly contorted; and we find the intermediate or Metalliferous group especially thrown into frequent and violent twistings, with, in many places, actual inversion. A continuation of the section eastward, beyond Plynlimmon (fig. 2), shows a similar appearance of the rock groups in reversed order of outcrop and with contrary dips, thus showing that Plynlimmon, like its more ancient and greater fellow Snowdon, stands in a geological valley or synclinal. We proceed to the detail of this section.

1. *The Aberystwyth grits* consist of beds of hard, compact, dark grey grit or greywacke, and dark shales, rabs, and imperfect slates in strikingly regular alternation, as may be seen in the ordinary photographs of the Aberystwyth cliffs.

The grey grits or greywackes are of great sameness and regularity both in structure and composition around Aberystwyth, being hard, grained rocks, often felspathic, regularly and sharply jointed. A cross fracture often shows a remarkable contortion in the lines of laminæ, this being, I believe, mostly of subsequent "concretionary" origin; many of the beds themselves are also, in part, of the same concretionary growth. The beds measure very constantly about 4 to 6 inches in thickness; and their under surfaces exhibit an abundance of raised markings, which are irregular or tortuous, branching, net-like or worm-like, these being also, in part, of concretionary origin.

The argillaceous partings are usually of about the same thickness as the greywacke-beds, sometimes thicker (especially to the east and south), sometimes thinner (as in many places around Aberystwyth). Most of their varieties are the result of subsequent metamorphic changes acting differently upon the rock according to a slight diversity of original constitution, or depending upon slightly different mechanical conditions. Thus have been produced the various forms of shivery shale, large platy shale, rubbly rab* of various forms and sizes, soft shaly slate, and even very well-marked regular slate in the Aberystwyth district. They are uniformly of dark colour, and never greatly indurated. Lenticular nodules with "cone-in-cone" structure are of frequent occurrence both in this and the following (or Metalliferous) series.

Fossils.—Fucoidal and worm-like markings are of frequent and wide-spread occurrence throughout this series, appearing for the most part in the form of raised markings upon the under surfaces of the grits. I have also found Graptolites in several localities.

Quarry at Cwm, on the south side of the Clarach Valley.

Monograptus Sedgewickii, *Portl.*
—— Clingani, *Carr.*
—— lobiferus, *M'Coy.*
Monograptus tenuis, *Portl.*?
Buthotrephis, small species.

* A *rab* is a fine-grained rock, usually argillaceous and not indurated, which readily breaks up into a rubble of cuboidal or prism-like fragments.

From the Bryn-y-Carnau Quarry near the old Water-reservoir, Aberystwyth.

Monograptus Sedgewickii, *Portl.*
—— crenularis, *Lapw.*?
—— lobiferus, *M'Coy.*
Monograptus tenuis?
Dictyonema delicatulum, *Lapw.* (n. sp.).

But the most important zone of fossils is found somewhat higher up in the series, exposed in a quarry formerly worked for building-stone and road-metal, in a field below Cefn Hendre, where we have collected

Monograptus Sedgewickii, *Portl.*
—— ——, var. distans, *Portl.*
—— Clingani, *Carr.*
—— lobiferus, *M'Coy.*
—— turriculatus, *Barr.*
Monograptus Hisingeri, *Carr.*
—— tenuis, *Portl.*?
Orthoceras, sp.
Calymene.

Many of these fossils were found in a set of thin, dark-grey, micaceous flags (the large-flag series), which are sometimes to be obtained of large size (4–6 feet square).

Dips and Foldings.—Many rock-foldings, some of them very violent and accompanied by fractures, are seen in our line of section, good examples being exposed near the second milestone from Aberystwyth; so that for a mile and a half along the Upper Devil's Bridge-road we appear to have only the same set of beds, repeated again and again by a number of rock-foldings (see section, fig. 1). But beyond this the easterly dip becomes more constant, and we appear to be traversing the outcrop of a continually ascending series.

2. *The Metalliferous-slate Group.*—In the Cefn-Hendre quarry, only about a mile and a half east of Aberystwyth, we already find a larger proportion of shales to grits than in the coast-section around Aberystwyth; and this change becomes still more marked in another quarry on the road-side further on down the hill towards Gogerddan. The same gradual though not perfectly regular disappearance of the grits to the east may be seen in our present section along the Devil's-Bridge road, as, indeed, in any other of the east and west roads from Aberystwyth*.

A change in the character of the argillaceous rocks appears in regular correlation with the loss of the grits. They become more and more indurated and cleaved, until, as the boundaries of the grit-series are reached, the normal cleavage of the district (striking N.N.E. and S.S.W.) is found even in the partings between thick grit-beds. Thus gradually do we enter into the territory of our second series—the Metalliferous Slates.

The hills of this district are barren and desolate, even more so than in the Aberystwyth-grit country; but they are decidedly more rounded and regular in their contours. Here, in the uplands, is a

* The limit of the grit series may be placed, as indicated by the yellow dots upon the Survey Map, at about three miles and a half east of Aberystwyth. In my pocket-book I find "at three miles from town, grits fewer and thinner than at Aberystwyth," at four miles "a few grit-beds as much as 6 inches thick," and at five miles "still a few thin grits."

vast dreary mountain-region of bare sheep-walks scantily marked out into districts by poor stone walls and wire fences, with much waste bog and peat land. The rocks are of uniform pale blue and grey colours, varying from small papery shales (rarer) to large irregular platy shale or regularly cleaved slates, also (in some areas) much indurated small slate rock cross-cut into fragments by frequent bedding- and joint-planes. Some zones of softer rab, like that of the Aberystwyth group, and a pale mudstone rab are sometimes found, especially near the junction with the grit series.

As we reach the central mining district, some seven miles east of Aberystwyth, beds of hard, pale, indurated slate-rock with frequent bed-bandings occur; and in the immediate neighbourhood of the mineral veins such induration is nearly always well marked.

Occasionally a bed of grit, 2–6 inches thick, occurs in this series; but such occurrences are very rare, so that the building- and road-stones of the central "Metalliferous" country have to be carried for miles, either from the Aberystwyth grit quarries in the west, or from the Plynlimmon group further east.

Thin ferruginous gritty bands, about $\frac{1}{2}$ inch thick, however, are more frequent, some of them being highly micaceous. Many such are seen between the fourth and fifth milestones and around the ninth milestone on the Devil's-Bridge road.

Rock-foldings.—Several excellent exposures of the contortions in this slaty series are seen along our line of section. There is a neat little synclinal at seven miles, an anticlinal towards the eighth milestone; and several folds may be detected about nine miles east of Aberystwyth; but overriding these foldings the prevailing dip is seen to be clearly and determinately to the east.

Fossils are rare in this series. The curious branching structure, *Nematolites Edwardsii*, Keep., occurs at Ty Llwydd; and I have found the Fan Algal (*Buthotrephis major*, Keep.), the Nematolites, and worm-trails (*Nereites*) in several other places. But in other areas, especially at Cwm Symlog and near Machynlleth, out of our present line of section, a rich Graptolite-fauna has been discovered, and will be described later on.

The Devil's Bridge, great Inversion of the Rocks (fig. 1).—As we descend the hill to the Devil's Bridge we pass over pale, hard, shaly slates* with thin gritty bands about 1 inch thick, marked with worm-tracks (*Nereites Sedgwickii*), impressions of the Fan Angal (*Buthotrephis major*, Keep.), and *Nematolites Edwardsii*, Keep. Coarse roofing-slates have been worked about half a mile west of the hotel. These rocks belong to the Metalliferous-slate series; but coming to the waterfall we meet with a set of alternating thin grits and large pale shaly slates, together with some large flags of laminated grit, with fossils exactly resembling those already noticed from Cefn Hendre.

Many of the grit bands are thin and little jointed, so that large

* Although the splitting of these rocks is so irregular and shale-like, yet the planes of division are of subsequent *cleavage* origin; therefore I call them shaly slates rather than slaty shales.

flags may be readily extracted, from which feature I have called this zone the "Large-flag series" (fig. 2). The dip is to the west, running under the slaty series. Fossils may be found here in the open quarry above the Devil's Punch-bowl, and along the sides of the waterfall itself; but all the Dendroid Graptolites (*Cladophora*) are from a band above the iron bridge in the waterfall-grounds; while some other beds below this bridge are so crowded with Crinoid ossicles as almost to merit the name of Limestone.

Fossils from the Devil's Bridge:—

Monograptus Sedgewickii, *Portl.*?
—— spiralis, *Geinitz.*
—— turriculatus, *Barr.*
Dictyonema venustum, *Lapw.* (n. sp.).
—— corrugatellum, *Lapw.* (n. sp.).
Calyptograpsus (?) plumosus, *Lapw.* (n. sp.).
Rhizograptus (?) digitatus, *Lapw.* (n. sp.).
—— ramosus, *Lapw.* (n. sp.).
Odontocaulis Keepingii, *Lapw.* (n. sp.).
Chonetes lævigatus, *Sby.*?
Orthis, sp.
Other fragmentary Brachiopods.
Phacops, n. sp.
Fragments of Encrinites.
Nereites Sedgwickii, *Murch.*
Myrianites tenuis, *M'Coy.*

Now in this list of fossils the species of Graptolites are seen to correspond with those of Cefn Hendre, the occurrence of *Monograptus turriculatus* in both places being an especially important fact, this being a species of very limited range.

And we have seen that they occur in identical rocks in the two places; I therefore cannot doubt that these are really one and the same set of beds, seen in the upper part of the Aberystwyth grits at Cefn Hendre and reappearing at the surface in an anticlinal at the Devil's Bridge.

This conclusion, however, is in direct antagonism with the stratigraphical appearances; for, notwithstanding the numerous folds, the predominance of the easterly dip is most determined and impresses itself strongly upon the mind.

Being convinced of these appearances, it was determined to test the thickness of the beds by actual measurement; and our exact observations and calculations, made at more than 100 exposures along the Devil's-Bridge road from Aberystwyth, strikingly confirmed our earlier impressions, giving, indeed, a result of nearly four miles thickness of strata (3 miles 1612 yards). In such apparent conflict of evidence, and in the absence of large faults, the only reasonable explanation is that the original natural order of the rocks has been destroyed by the formation of a great inversion, or rather, as I believe, a series of inversion folds in the Metalliferous-slate series (see fig. 1). And indeed this interpretation, in conformity with the fossil evidence, is independently almost demanded to explain away the enormous apparent thicknesses of similar rock-beds as measured from their present dips.

We may then safely conclude that in the Devil's-Bridge rocks we are again upon the upper part of the Aberystwyth-grit series.

Continuing our section eastward over the hill through the Arch to Cwm Ystwyth (fig. 2), we still traverse a series of shaly slates of the "Metalliferous" type, with here and there thin grits apparently belonging to the Large-flag series. The presence of Fucoidal markings, including the Net Algal (*Retiofucus extensus*, Keep.) and *Nematolites* at one mile and a half from the Devil's Bridge, also serves to indicate our proximity to the Aberystwyth-grit series. The general apparent dip is clearly eastward, with some foldings.

Descending beyond the Arch towards Eglwys Newydd the only matter of special interest is the occurrence of a thin seam of rottenstone (a decomposed limestone) which may perhaps correspond with the crinoidal zone in the Devil's Bridge. Such rocks are of very rare occurrence in Mid Wales, so that it is a popular saying that "there is no lime in Cardiganshire."

The rocks around Popty, near Eglwys Newydd, are again seen to be very much of the Devil's-Bridge type; and I am inclined to think that a set of rock-folds with reversals have here brought that fossil zone near to the surface again. We now reach a region of manifest great rock-foldings; and as we ascend Cwm Ystwyth a number of exposures display an important westerly fold in the rocks. The beds appear still to belong to near the junction of the Aberystwyth grits with the Metalliferous-slate group.

Next we pass through the rich metalliferous district of Cwm Ystwyth with its network of mineral veins in the Metalliferous-slate group, beyond which, at Blaen y Cwm, thicker grits (about 2 feet) with east and south-east dips come in amongst the slates; and these latter become replaced over a considerable area by dark shaly slate, rab, pencil-rab, and other softer forms of the argillaceous rocks.

Thick grit-beds, which are cleaved, next form a prominent feature at Craig Lluest (fig. 2); and these I regard as belonging to the lower part of our upper grit-series—the Plynlimmon group. This series is better developed in Plynlimmon itself, to which we must refer (*infrà*, p. 156) for a more detailed description. The dip is eastward.

Some three quarters of a mile beyond the top of the pass the dip changes, a westerly slope setting in; and this remains well sustained, though with some east foldings, on to the hills west of Rhyader. Here, then, we see the eastern half of the great axial synclinal of this part of Wales—a great fold in which Plynlimmon lies; but its apparent magnitude is greatly exaggerated by the phenomena of reversed dips. The lithological details of this part of the section in its frequent slight variations, but general monotony, till we reach Rhyader, would occupy much space and be of little value. Some pale shaly slates approaching the character of the Tarannon shales, and thin gritty bands, are seen on the dreary bog- and moorland of the higher plateau and on the east of the pass, where also some of the grits exhibit irregular fucoidal markings and the Net Algal (*Retiofucus extensus*, Keep.) upon their under surfaces.

One good anticlinal fold in "Metalliferous slates" with some grits has its axis about one mile and a half east of Aber Gynwy; and a synclinal in the slaty series is indicated lower down on the road to Pont ur Elan. The well-sustained general westerly dip of the great series of thin-bedded slate, pale- or dark-coloured, seen in the ascent from this bridge to the top of the high part of Rhyader, appears to show these rocks as in regular serial continuity with the beds passed over on the great slope next to the west, the whole forming the vast westerly fold complementary to the great easterly dip of the Metalliferous-slate series between Aberystwyth and the Devil's Bridge. And just as the latter is now proved to be not one continuous series, but really a much smaller group affected by frequent inversion, so we are, I think, justified in adopting a like interpretation for these beds to the east of the Plynlimmon axis. The correspondence of the rocks on the two meridional sides of this axis is further illustrated as we reach the eastern edge of the great plateau above Gwyn Llyn (fig. 2), where we find a zone of pale banded and indurated slate rock identical with the Strata Florida slate rock used in the Aberystwyth stone pier. These pass under a series of grits and conglomerates in the beautiful valley of Cwm Elan. A little further south these latter beds reappear in the Gwastaden grits and conglomerates of the hills east of Rhyader. Thus our accumulated facts support the view that there are two distinct series of grits in Cardiganshire, separated by the Metalliferous-slate group. The Rhyader grits and conglomerates appear to be nearer to the Plynlimmon than the Aberystwyth group.

The Aberystywth Grits, extent, variations, &c.—A glance at the yellow-dotted area upon the Geological Survey Map will show that the Aberystwyth grits form a crescent-shaped patch of country in the centre of the western Welsh border, extending from near Borth, some five miles north of Aberystwyth, to Traeth Bach, south of Llangrannog, a distance of thirty miles, and with a maximum breadth, at Mynydd Bach, of nine miles.

A set of characteristic surface-features marks off its boundaries with tolerable distinctness, its barren or gorse-covered ridgy hills, elongated along the line of rock strike, and with minor sets of parallel crests and ledges (sometimes forming sets of small step-like structures or inclined ribs in the lines of more durable grit-beds), giving to the group an almost unmistakable appearance*.

The general characters of the rocks have already been described in our Devil's-Bridge line of section; and the variations from those types are neither numerous nor very striking. The greywacke and grits are very constant in grain, never becoming conglomeratic; but some coarser varieties are found in a few localities—for example, around the Eiddwen lakes, Mynydd Bach, and at Pen Craig, north of Llanilar. In these places the greywacke is almost granitoid in appearance, the quartz grains being large, flakes of mica common,

* It was pointed out long ago by Sir Henry de la Beche that the same type of physical features appears in the area of the grits of Penrhyn ddu in the Lleyn peninsula, which are marked Lower Cambrian upon the Survey Map. To me this resemblance also appeared very striking. The Penrhyn-ddu beds are totally unlike any of the Longmynd group known to me; and I cannot believe they are of such an age; nor do I think with de la Beche that they are of the same age as the Aberystwyth beds, but regard them as an exceptionally developed type of the Tremadoc series.

and crystals of felspar, sometimes perfect but more often fragmentary, very numerous and conspicuous. These constituents are held together in the dark argillaceous greywacke matrix. The rock often closely simulates a volcanic ash*.

In thin sections, examined under the microscope, the Pen-Craig rock exhibits irregular angular and subangular fragments of quartz and felspar, the interstices filled with the dark, opaque (argillaceous) matrix. The quartz is somewhat cracked, and includes numerous cavities and minute spicular microliths; these latter are grouped into wavy stratoid zones, between which the principal cracking of the quartz runs. The felspar is mostly in the form of very angular crystal-fragments, usually much decomposed, and of powdery appearance; but some of the better-preserved fragments show the characteristic ribbon banding of the Plagioclase group when examined with polarized light.

The ordinary finer-grained beds are usually of darker colour than these, and contain less felspar; they are, however, for the most part quite similarly constituted, the felspar crystals often being readily recognizable when decomposed into irony spots over the weathered portions of the rock. Paler thin bands, very compact in texture, occur in the southern part of the district around Llangrannog.

The presence of crystals of iron-pyrites occasionally gives a marked feature to the grits; and at Pen Craig, Llanilar, and in the Garthen valley, Eglwys Fach, some beds occur beautifully studded with these brassy cubes.

The ordinary thickness (4–6 inches) of the beds is very constant throughout the area of the Aberstwyth grits; but more massive beds (1–1½ foot) occur under Allt wen and at Aberaeron, in the Garthen valley, and at Llangwyryfon (2½ feet). At Cefn Coch, Pen Pegwyns, and along the coast south of Aberystwyth still thicker beds are seen (3–4 feet); they are worked for building-stones. At the southern limit of the series, near Llangrannog, the grits become thin, irregular, and inconstant, thus gradually dying away, to be replaced by the argillaceous slate-rocks.

Two structural peculiarities are very characteristic of the Cardiganshire grits—namely, the remarkable contorted lamination seen on a fractured surface, and an abundance of fucoid markings, together with strange-looking ripplings, ridgings, volutings, and other raised forms of structure found upon the undersurfaces of the grit-beds†. The rock is jointed, sometimes into large blocks good for building- and flag-stones, but often much more closely into regular oblong or rhomboidal fragments. At Allt-wen cliff and elsewhere it is divided up into oblong, prismatic, or rudely lozenge-shaped fragments a foot long, forming a kind of coarse grit-rab.

* This abundance of felspar crystals, so general in the Silurian rocks (Upper Silurian of North Wales, South Wales, and the Lake-district), points to the neighbouring presence of a vast mass of early, perhaps primæval, igneous rocks as the great source of sediment-supply in Silurian times.

† It is proposed to give a more particular account of the rock-structure of Cardiganshire in a separate paper.

Little need be added to what we have said on the alternating argillaceous beds. The *rab*-type is best seen upon tho Allt-wen cliffs, south of Aberystwyth, where also an elongated type, serving very well as rough pencils, forms the "pencil-rab;" these beds commonly appear much more solid in the heart of the rock, the fragmentary structure only becoming developed after exposure to weathering.

The cleavage phenomena here are often of peculiar interest from their frequently incomplete, half-developed character. The dark shaly-looking rock of Constitution Hill, Aberystwyth, would not at first be suspected of a slaty structure; but specimens may be gathered with the cleavage seen distinctly cutting across the stripe-lines; and many of the dark, soft, shaly rock-beds of the neighbouring cliffs, when seen *in situ*, will be found to have their divisional lines running *across* the bedding.

A pale, homogeneous, hardened mud, or pale mudstone, splitting with curved, conchoidal surfaces into 2–3-inch blocks, is of additional importance, as probably marking a zone; I have found it some half a mile north-east of Nant Eos, at Pen Craig, Llanilar, on the road-side N.N.E. of Llanbardarn, and at five miles east of Aberaeron. This appears to indicate a distinct zone near the top of the Aberystwyth grits. The same kind of rock occurs at Llyn Fyrddyn Fawr, and at Rhôs Rhydd, near Llantrisant, where it is again not far removed from the thin-flag series—another zone at the top of the Aberystwyth grits.

The Large-flag series.—This series, which belongs to the upper part of the Aberystwyth group, is best marked to the east, in the neighbourhood of the Devil's Bridge and Llantrisant, where its presence is soon made manifest in the construction of piggeries and other low huts, whose sides and roofs are covered with the flags. These are grit-beds, about 1 inch thick, but little jointed, so that large slabs, frequently 4 and 6 feet square, are commonly extracted for use in the neighbourhood. The rock is fine-grained, and usually exhibits a complete contortion in the lines of laminæ; altogether it much resembles some of the grit-beds of the middle Lingula-flags of North Wales. The surfaces are generally undulated, and often show true ripple-marks, over which we find Graptolites and other fossils spread out: the Devil's-Bridge Dendroid Graptolites occur in this series.

The further extensions of these beds, north and south, are seen around Pont Erwyd and south of Llantrisant; and the same series seems to be brought up to day by folds, on the east at Eglwys Newydd, and to the west near the head of Cwm Symlog. Bands of rottenstone (decomposed limestone) occur at the Devil's Bridge, near Eglwys Newydd, and again in the hills some four miles east of Tal y bont.

Around Aberystwyth these flags are not so well developed; but they may be recognized at Cefn Hendre, as already described, where they are put to the usual purpose of hut-making for the workmen's shelter.

Fossil localities, other than those already given, are:—

Parson's Bridge, and Temple Mine, south of Pont Erwyd.

Monograptus lobiferus, *M'Coy.*
Climacograpsus scalaris, *His.*
Nereites Sedgwickii, *Murch.*
Myrianites M'Leayi, *Murch.*
Buthotrephis major, *Keep.*

Cefn Coch, near Aberystwyth.

Monograptus Sedgewickii, *Portl.*
Buthotrephis major, *Keep.*
—— minor, *Keep.*
Retiofucus extensus, *Keep.*
Palæochorda tardifurcata, *Keep.*

Constitution Hill, Aberystwyth; Wern Grug, Llanilar; Mynydd Bach; Plas Crag, Llanbardarn, and other places have also yielded a few fossils, mostly Algæ,—*Buthotrephis major*, *B. minor*, *B. minimus*, Keep., *Palæochorda tardifurcata*, *Retiofucus extensus*, and *Nematolites Edwardsii*, Keep.

Thickness.—We have seen that much of the apparent thickness of the Aberystwyth grits is deceptive, being explained away by great folds. Still a great series remains, well attested even by the simple heights of many hills which are built up entirely of this group. Mynydd Bach appears to be over 1000 feet high (by aneroid); and I should estimate the group at certainly not less than 1000 feet of maximum thickness. Our detailed measurements along the Devil's-Bridge road show a thickness of 1639 yards, or nearly one mile.

The Metalliferous-slate Group.—A very large part of Cardiganshire is constructed of this series. In the special area of our work it forms a broad semicircular zone, some eight to ten miles across, sweeping around the dome of the Aberystwyth grits to form all the slaty country from north of Cardigan up to Machynlleth. At the latter place it forks into two, the main curve being continued out to sea by the Dovey valley, while a broad but rapidly attenuating arm runs northward to Dinas Mowddwy, at which place its much diminished representative is found between the Bala series and the Tarannon shale.

The above area, however, is not unmixed metalliferous slate, the upper part of the Aberystwyth group being brought up by folds, along north-and-south lines, running through Ystrad Meurig, and the Devil's Bridge; and possibly some outliers of the Plynlimmon group may be folded in. Still the general absence of arenaceous beds is marked over miles of country without a single grit-bed to serve for road- or building-stone. Tin Llidiart village uses the hard pale slate of Goginan for building; and at Llanafon the numerous boulders serve for road-metal.

Further south, in the line between Cardigan and Llandovery, the slate series appears in still greater extent, which is due to its there representing also the Aberystwyth group, and perhaps also the Plynlimmon grits, these groups not being developed *as such* in that area.

A marked lithological character distinguishes this group as a whole, the terms "indurated shaly slate," "irregular slate," "flaggy slate," "pale blue slate," from my note-book, serving to indicate the usual character; I also find "hard pale slate-rock, often much jointed," and "pale slates with ribbon bandings." The prevailing colour of the rocks is a pale blue-grey; and they generally break up into moderately small fragments, shale-fashion.

Slate.—In many places where the slates are better cleaved, and less frequently jointed, they are worked in small quarries for inferior local purposes, as around Llancynfelin, in the hills south of Machynlleth, in the island mounds of the Gorsfochno flats, and near the Devil's Bridge. These rough slates are pale-coloured, hard, and coarse: but around Machynlleth thoroughly good slates are worked in a number of large quarries. One of the largest of these is at Pont Faen, where large slate-flags are extracted; but the most interesting to the geologist is that at Morben, two and a half miles south-west of the town of Machynlleth. These are thick-bedded slate rocks, with a few thin grits, dipping at high angles to the W.N.W.

This, however, is an *inverted dip*, as is proved by the position of the prominences on the grit-bands, which are upon the *upper* surfaces of the grits, the worm-trails being also manifestly in inverted position. The cleavage-dip diverges only slightly from the bedding-dip, so that the Graptolites usually run for some distance along the surface of the slate, and then gradually skim under it. The slates are very good, dark and soft. Nodules of iron-pyrites occur; and nearly all the Graptolites are converted into this bright mineral. This quarry has yielded the finest of our fossils, the *Monograptus Sedgewickii* being especially magnificent.

Fossils from Morben Quarry, Machynlleth.

Rastrites peregrinus, *Barr.*	Monograptus Hisingeri, *Carr.*
—— maximus, *Carr.*	—— tenuis, *Portl.*
Monograptus Sedgewickii, *Portl.*	—— involutus, *Lapw.*
—— ——, var. spinigerus, *Nich.*	Diplograpsus Hughesii, *Nich.*
—— ——, var. distans, *Portl.*	Climacograpsus normalis, *Lapw.* ?
—— intermedius, *Carr.*	Myrianites M'Leayi, *Murch.* ?
—— spiralis, *Geinitz.*	—— Lapworthii, *Keep.*
—— lobiferus, *M'Coy.*	Buthotrephis major, *Keep.*

Below this in present position, but by inversion really above it, is a zone of pale blue and olive shaly slate, pointed out to me by Mr. J. E. Marr, F.G.S., as being similar to certain zones in the Coniston mudstones. The great slate district of Corris, usually referred to the Llandeilo age, is in this series, as will be shown later on; also the excellent slates of Dol y Mynach and Cwm par Adwys, west of Rhyader.

Other rock-varieties, such as dark paper-shales, rab, and mudstone, approach near to the Aberystwyth types; and some of the occurrences of such rocks doubtless indicate the uprising of that group as inliers in the metalliferous-slate area. In the Devil's-Bridge road such rocks appear in several places.

Grit-beds as thick as 6 inches may occur; and thin zones, about $\frac{1}{2}$ inch to 2 inches thick, are frequent; these are generally red-stained at the surface, and micaceous. They are trustworthy guides to the dip of the beds, which in their absence is often not easy to discover.

At Cwm Symlog, nine miles east of Aberystwyth, pale soft shales and slates with thin grits, rich in fossils, are found.

Fossils from Cwm Symlog.

Rastrites peregrinus, *Barr.*
Monograptus Sedgewickii, *Portl.*
—— crenularis, *Lapw.*
—— cyphus, *Lapw.*
—— gregarius, *Lapw.*
—— intermedius, *Carr.*
—— Clingani, *Carr.*
—— spiralis, *Gein.*
—— lobiferus, *M'Coy.*
—— runcinatus, *Lapw.*
—— Hisingeri, *Carr.*
—— tenuis, *Portl.*?
—— involutus, *Lapw.*
Diplograpsus tamariscus, *Nich.*?
—— Hughesii, *Nich.*
—— sinuatus, *Nich.*
Monograptus palmeus, *Barr.*
Climacograpsus spiralis, *His.*

FORAMINIFERA.

Dentalina.
Textularia.
Rotalia.

ANNELIDA.

Nereites Sedgwickii, *Murch.*
Myrianites M'Leayi, *Murch.*
Nemertites Olivantii, *Murch.*

ALGÆ.

Buthotrephis major, *Keep.*
—— minor, *Keep.*
—— minimus, *Keep.*

At Ystrad Meurig, forming the high ground twelve miles south-east of Aberystwyth, and in near association with a fossil zone, is a series of hard pale grits with thin indurated slate partings, firmly bound together, to form hard massive rocks (*a*); we refer to this as the "Strata Florida rock."

Another well-marked rock demanding attention is (*b*) a pale indurated slate rock, usually cross-banded by thin arenaceous stripe-zones. It is well seen at Machynlleth, to the east of Eglwys Fach, and east of Tal y bont. Again, the same type of rock occurs (*c*) in the hills east of the Rheidol gorge; I find blocks of it around Llantrisant; and it is also well developed at Goginan, to the east of Llanddewi Brefi, and in the hills west of Rhyader. These rocks are essentially similar to those of Ystrad Meurig, only less arenaceous; and I include them all under the name of "Strata Florida rock."

Now, classifying these various localities of the Strata Florida rock, we find they fall into a set of definite lines having similar relations to neighbouring rock-beds, and indicating, as I believe, definite zones. First, the more arenaceous rock of Ystrad Meurig is in the same north-and-south line with Cwm Symlog and with Llantrisant; and in the first two of these places it is in near relation with a rich fossil zone. Also it is about in the same line with the Large-flag series, as seen in the Devil's-Bridge road, nine miles east of Aberystwyth, also found at Llantrisant and Cwm Symlog. In these places we have, then, evidence of the occurrence of this hard pale slate rock along a definite line of country in near association with the Graptolite fossil-zone and the Large-flag series. Next we find that the group *b* also falls into a line east of Aberystwyth; and here, again, it is associated with the great fossil zone at Machynlleth, while near Tal y bont it is connected with a band of rottenstone like that of the Large-flag series at the Devil's Bridge.

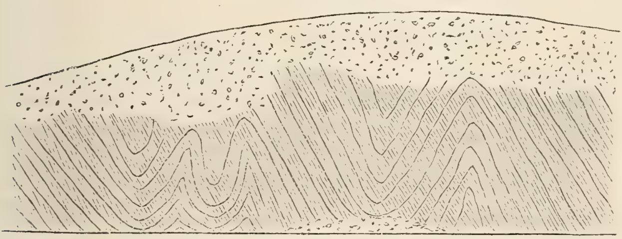
Altogether, then, the result of these lithological correlations is to support our theory of four different lines of north-and-south foldings between Aberystwyth and Plynlimmon—namely, (1) the principal axis of Aberystwyth, (2) the principal axis of Plynlimmon, and (3) the two minor axes running (*a*) from Ystrad Meurig through Llantrisant and Cwm Symlog, and (*b*) along the gorge of the Rheidol about Pont Erwyd and the Devil's Bridge. The further northward extension of (*a*) is probably indicated by the grits of Yr Carreg and Moel y Llyn. These minor folds have not been recognized further south; and, indeed, we might expect them to disappear as the lateral spread of the beds becomes restricted.

At Lampeter the well-known olive shales and grits with *Nereites* &c. are exposed in quarries. The grits are in thin beds (2–4 inches), hard and laminated, with partings of shale either light (olive) or dark in colour; no cleavage is seen. The fossils are:—

Nereites Sedgwickii, *Murch.*
—— cambrensis, *Murch.*
Myrianites M'Leayi, *Murch.*
Nemertites Olivantii, *Murch.*
Palæochorda tardifurcata, *Keep.*
Retiofucus extensus, *Keep.*

also other worm-like and algoid markings. Altogether this is a pretty typical metalliferous slate, though more arenaceous than is common.

Fig. 3.—*Railway-cutting between Traws Coed and Caradoc Waterfall*, 1877.



Contortions.—The woodcut (fig. 3), representing a railway-cutting east of Traws Coed, illustrates some of the frequent and sharp contortions of this series. All the perceptible foldings, however, numerous and striking as they are, are far from adequately showing the real complexity of the infinite twistings and inversions of this series, the existence of which is proved principally by considerations from the fossil evidences. Without fossil evidences it is, as a rule, impossible to detect inversions; but still, in those places where grits with fucoidal markings &c. occur, we have another key to the true relations of the rocks—namely, in observing the positions of the curious prominences upon the surface of the grit, these being normally always upon the under surfaces; but where the beds are inverted (as at Morben, Machynlleth, &c.) they are found upon the upper surfaces, the true worm-trails (*Nereites* &c.) being in this case impressed upon the under surfaces, in inverted position.

These inversions explain away in great degree the enormous apparent thickness (miles of strata) of this series; but a very great vertical series still remains well attested in actual steep and precipitous mountain-sides, from 500–1000 feet high, and I cannot estimate the group at less than 2000 feet.

Fossils are almost entirely wanting in this series, except, I believe, near the base, where I would place the rich beds of the Morben Quarry, Machynlleth, and Cwm Symlog. The fauna is intimately related to that of the Aberystwyth group, as indeed was to be expected; for the fossils of this latter group occur in its higher part, not far removed, in serial order, from the Metalliferous-slate fossil-zone.

The worm-like and fucoidal markings, *Nereites*, the Fan Algal, and the *Nematolites* are widely distributed throughout the series, worm-trails being very characteristic.

Other fossil localities are:—

Llantrisant, with the large Fan Algal (*Buthotrephis major*) and *Nematolites tubularis*, Keep.; the Llyfnant valley, with *Climacograpsus scalaris*, His.; Dyffryn Castell, with *Climacograpsus scalaris*, worm-tubes, and the *Nematolites*, also some of the shells recorded by Sedgwick; and Steddfa Gurig (west of), with *Monograptus Sedgewickii*, Portl., *M. tenuis*, Portl.?, *Climacograpsus scalaris*, His., and *Orthoceras*. Above Taliessin, fragments of dendroid Graptolites and *Nematolites tubularis* occur; and the latter is also found at Llantrisant, Ty Llwydd, on the Rheidol, and elsewhere.

Richer localities are:—

West of Lisburne Mine, Ystwyth Valley.

Rastrites?	Climacograpsus scalaris, *His.*
Monograptus Sedgewickii, *Portl.*	Nereites Sedgwickii, *Murch.*
—— spiralis, *Gein.*	Buthotrephis.
—— lobiferus, *M'Coy*,	

Garthen Valley, Melin Newydd.

Monograptus Sedgewickii, *Portl.*	Orthoceras, sp.
Climacograpsus scalaris, *His.*	

The numerous metalliferous veins (lead and silver) in the rich mining-districts of Cardiganshire are almost confined to this set of beds; hence the name here given it.

3. *The Plynlimmon Group.*—As we ascend the mountain-slopes along the valley of the Rheidol, above Pont Erwyd, we meet with the rocks of the upper grit series, which form the upper part of the Plynlimmon mountain. Around Garn Fach some of the grit-beds are seen, of rather coarse type, sometimes assuming a very granitoid aspect, there being a profusion of felspar crystals and large blebby quartz grains. The felspar crystals may be of large size; and some of them are perfectly preserved and glassy. Doubtless the rock is the direct result of the degradation of an ancient acidic igneous rock.

Conglomerate beds, consisting of pebbles of white quartzite and vein quartz in a grit matrix, are also met with; but they are few. The group here is still, in the main, a slate series, some of the slate being pale and papery, of the "pale-slate type." Iron pyrites is common in both grits and slates. The main dip is decidedly easterly.

Mounting the higher ground above Nant y Moch the grits become more conspicuous, forming a terraced structure by their outcrops around the hill; and near the summit a rugged steplike structure is produced by the regularly bedded fine-grained grit series. The finest exposure of these Plynlimmon grits is in the magnificent precipices fronting the Rheidol lake (Llyn Llygad Rheidol), where many of the beds are very thick (7–10 feet) and of moderately coarse grain. A particular feature in them is their regular columnar jointing; this is quite as regular as in many columnar felsites, numerous columns, 7 feet long, being seen running right across the beds. Conglomerates are uncommon; but some three or four beds of beautiful "pudding stone," with white quartz pebbles in a felspathic sandstone matrix, are seen upon the western slope of the mountain.

Coarser beds of this group are probably indicated by a large boulder upon the hill-top above Gogerddan House, near Aberystwyth, which has pebbles as big as cannon-balls.

These grits form a crescent zone from north of Plynlimmon through the high ground of Mid Wales, running east of Tregaron and east of Lampeter; but they die out beyond this to the south. They constitute the genuine backbone of South Wales, lying in a synclinal. The highest beds form the upper ground of Plynlimmon itself. In the Teifi area the beds are remarkable for being coarsely cleaved into large tiles about ½ inch to 1 inch thick, a structure which graduates into jointing on the one hand and true slaty cleavage on the other. Similar cleaved grits occur around Llyn Fyrddyn and on the hills east of Lampeter, all of which I would place on the same horizon. There is, however, some doubt in my mind as to the exact position of this horizon in the geological series.

Foldings.—As a group, the Plynlimmon grits are characterized, not by violent contortions or sharp bendings with fracture, but by broad and gentle foldings. These are beautifully seen around the Teifi lakelets and Llynodd Ieuan; also at Llyn Fyrddyn Fach and Llyn Fyrddyn Fawr, and Llyn Bugeilyn, where the ridges and minor hog-backs of the surface correspond with the structural anticlinal and periclinal foldings of the rocks with great regularity and clearness.

Amongst the rock-varieties we may notice blue shaly slates, blue slates in 6-inch beds, cleaved into oblong flags about ½ inch thick (Llynodd Ieuan), and arenaceous mudstone, broken up into coarse rab, the fragments measuring 1–3 feet × 3 inches × 1 inch, also smaller rab.

The lithological differences between this series and the Aberystwyth group are the greater thickness of the grit beds, the presence of quartz conglomerates, and the rarity of curious rock-surfaces and fucoidal markings. The slates also are, as a whole, of paler type.

Fossils have not been discovered in the grit series of the Plynlimmon mountain; but large boulders of coarse conglomerate upon Gogerddan Hill, Aberystwyth, which surely came originally from this mountain, contain casts of various fossils, of which I can mention crinoid ossicles, *Nebulipora?*, *Petraia*, a large cup coral, and *Meristella*.

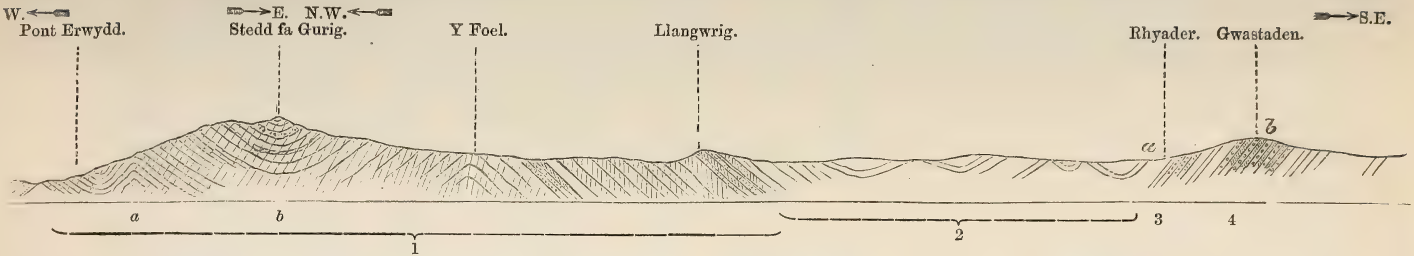
The *thickness* of this group must also be very great; for Plynlimmon rises some 1500 feet above Garn Fach, the level where the Plynlimmon grits first appear. A thousand feet is probably an under-estimate.

Part II. *Brief Notes upon other Sections.*

(1) *From Aberystwyth through Pont Erwyd to near Builth* (fig. 4).—From Aberstwyth to Pont Erwyd the section is similar to that from Aberystwyth to the Devil's Bridge; but the western dips are more important towards Pont Erwyd, so that the inversions required are here smaller or less numerous. Beyond Pont Erwyd is a great slate and shale series running for many miles, nearly to Rhyader, and forming by the apparent dips an important synclinal under the highest ground south of Plynlimmon. Fossils occur at Pont Erwyd and Dyffryn Castell, also near Rhyader. The hard pale-slate series comes in at Goginan and east of Pont Erwyd, and there is a similar rock west of Rhyader; but the Plynlimmon grits do not actually appear as such, unless the grits of Llynodd Ieuan belong here; they are, however, well developed in the mass of Plynlimmon further north. Some of the paler slate along our line of section may represent this series. Grit beds similar to those of the Aberystwyth group are found in two places near the 'Glansevern Arms,' and again further on east of Langwrig. They are to be regarded as special local developments in the Metalliferous Slates. Other grits and conglomerates seen at Gwastaden are probably the representatives of the Plynlimmon grits.

(2) *Section from Llandeilo to Aberaeron.*—Three principal grit-areas are met with in the line of this section—namely, at Talieris (west of Landeilo), east of Lampeter, and at Aberaeron. The Talieris conglomerate beds are surmounted by dark shales and shaly slates of the Metalliferous types; and beds of the Rhyader pale-slate type next underlie the grits of the country east of Lampeter. By an exceptional appearance the Metalliferous slates of the west seem to underlie the Aberaeron grits. No pale slates are seen beneath the Talieris conglomerate beds. The principal axial fold in the section seems to be a synclinal in the Teifi valley by Lampeter—the mountains to the east and west of this being (that is, if the rock-dips have *any* truth in them) great anticlinals in the Metalliferous-slate and Rhyader Pale-slate series. The beds of grit and conglomerate at Talieris are not of the nature of basement beds of a stratigraphical group, but indicate nothing more than such slight physical variations as a shallowing of the sea-bed or a change in the direction of the currents, resulting in the formation of sand and pebble banks; for the pebbles are not fragments of the underlying rocks, and there is no trace of any physical break or even change of lithological character above and below them.

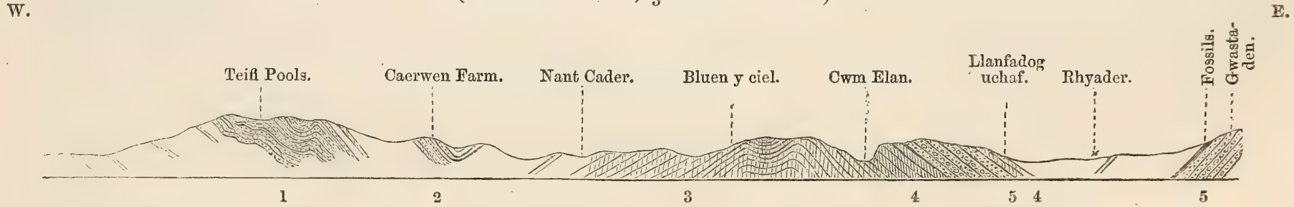
Fig. 4.—*Section from Pont Erwyd through the Plynlimmon axis to Llangwrig and Rhyader.*



1. Metalliferous-slate series, with a few thin grits.
2. Drift-covered country.
3. Pale slates.
4. Conglomerates.

a. Inversions?
b. Plynlimmon synclinal.

Fig. 5.—*Section from Strata Florida and the Teifi Pools to Rhyader and Gwastaden.*
(Horizontal scale, $\frac{1}{3}$ inch to a mile.)



1. Dark grits, shales, and slates.
2. Thin grits and flags, and shivery slate.
3. Pale slates and shales.
4. Pale slates.
5. Grits and conglomerates.

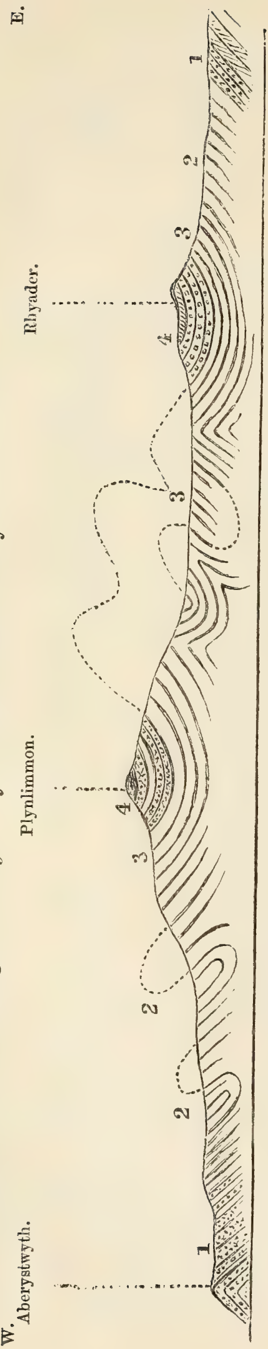


Fig. 6.—*Diagram of the General Structure of Central Wales.*

1. Aberystwyth grits.
2. Metalliferous-slate group.
3. Rhyader pale slates.
4. Plynlimmon grits.

(3) *Rhyader to the Teifi Pools* (fig. 5).—In this section three main folds are indicated, namely a central anticlinal fold at Disgwylfa in the Rhyader pale slates, with a synclinal on its east and west. The former is a comparatively simple basin of pale slates beneath the grits and conglomerates of Cwm Elan and Gwastaden; the latter, corresponding with the Plynlimmon synclinal, is a much more complicated structure, probably much affected by reversals.

General Result of the East and West Traverses (see fig. 6).—The sections just indicated show that the great area of Mid Wales is made up of a thick series of imperfect slates, pale slates, shales and grits, having a general resemblance and intimate connexion throughout, as of one continuous group, but divisible into the subgroups indicated in the beginning of this paper.

These rocks form one great primary synclinal extending from the Aberystwyth axis to the east of Rhyader, and from the west of Llandeilo to Aberaeron. For in the west of Cardiganshire we find a great and continuous course of easterly dips running inwards from the coast; and in the eastern half of the area, in Radnorshire and Caermarthenshire, is a corresponding grand set of westerly dips. Subordinate but still very great anticlinal folds along north and south axes bring up on the east the Metalliferous slates between Plynlimmon and Rhyader, and on the west the upper part of the Aberystwyth grits, in the line of Pont Erwyd and the Devil's Bridge. Another, smaller fold with the same result as the last, runs from Ystrad Meurig northwards towards Machynlleth, thus greatly swelling out the surface-area of the Metalliferous-slate series.

Minor foldings, also with north-and-south axes are infinitely abundant over the whole district, with frequent inversions which obscure the original order of the rock-beds.

Included in these foldings are four principal crescent zones of grit, greywacke, and conglomerate, namely:—1st, the western or Aberystwyth grits; 2nd, the eastern grits—an imperfect line of grits seen at Talieris, west of Llandeilo, and perhaps continued in other grits East of Gwastaden. These I regard as the diminutive representatives of the Aberystwyth grits. 3rd. The Plynlimmon grits and conglomerates, with much associated pale slate; and 4th, the grits and conglomerates of Cwm Elan and Gwastaden, which are also associated with, and, indeed, included in, a great pale-slate group, the Rhyader pale slates. The last two are upon the same stratigraphical parallel, occupying synclinals. These grits I do not regard as necessarily holding exactly the same horizon over wide areas, they having been probably shingle banks over the old sea-bottom. The pale slates seen in so many sections appear to belong to two principal horizons—(*a*) the lower or Strata Florida pale slates in the lower part of the Metalliferous-slate group, and (*b*) the Rhyader pale slates, associated with the Cwm Elan, Gwastaden, and Plynlimmon grits.

More distant Sections (see Table of Vertical Sections, p. 164).

In order to work out the relations of these rocks to the other lower palæozoic groups, I have visited various districts where the Cardiganshire series might be studied in association with rocks of some definite and decided horizon—namely, amongst other places, Llanbrynmaer, Dinas Mowddwy, Cardigan, N. Wales, &c.

In the Llanbrynmaer area we find (1) an upper series of grey grit and greywacke, often very felspathic and micaceous, cleaved, and with fragments of fossils (the Denbighshire grits). These pass down by gradual transition into (2) a series of pale blue and green, grey and purple shales, with some darker shale, rab, and green grits, which make up the true Tarannon shales; some obscure fragments of Graptolites have been found here. Again, there is no break, but a simple passage between this series and (3) the lower series of grits, greywacke, and dark shales which belong to the Cardiganshire type, and contain the fossils of our Metalliferous group. To the west of the Tarannon plateau we find the Metalliferous slates fully developed in the Pennant valley, with the characteristic fossil species, and the usual associated lead-mines of that group.

The whole character of this Metalliferous slate is different from that of the Tarannon shale; and our evidence points uniformly and decisively to the Metalliferous slate being a more ancient series, the two groups being separated in this area by a zone of grits. The Plynlimmon grits and associated pale slates, as seen in Plynlimmon and around Rhyader, appear to be wanting in this area, there being no well-developed grit series between the Llandovery group and the

Denbighshire grits. We shall find reason to believe that they are represented, feebly it is true, by the thin grit-beds above described in the Tarannon shale.

The Dovey Valley : Section across the valley near Llan y Mowddwy (fig. 7).—This section gives, in a narrow area (measuring less than 2 miles across), the complete series from the Lower Bala slates to the Denbighshire grits. The Denbighshire grits pass down into the Tarannon shales, which are pale-slate rocks resembling the Rhyader pale slates. There is, again, no break between these and the series of greywackes and dark shales and slates beneath. This latter group (which is in part the Lower Llandovery of the Survey) agrees both in its lithological characters and in its fossils, so far as known, with the Aberystwyth grits.

There is no distinct basement bed of conglomerate or grit to this series, such as might indicate the existence of an important stratigraphical break ; but, on the contrary, there is every appearance of a passage from the underlying great slate group up into the true Silurian series. This great slate group corresponds in its general lithological characters and its "cone-in-cone" nodules with our Metalliferous slates ; but I have not detected any pale slate in them. In the absence of fossils, it is not possible to determine their exact age ; but they should probably be regarded as belonging for the most part to the Upper Bala slate group. I should, however, expect some of its upper beds to be the representatives of our Cardiganshire Group, the lower part (Upper Bala) corresponding with much of the slate group between Cardigan and Llangrannog, about to be described.

It is further noteworthy that in this line of section, as in the Cardiganshire Group, the newer rocks are much better cleaved, and appear altogether more highly metamorphosed than the more ancient rocks to the west.

Corris Area.—The great slate district of Corris, usually referred to the Llandeilo age, belongs to our Metalliferous-slate group, as is proved by the following fossils from Corris and Taren y Gesail :—

Monograptus Sedgewickii, *Portl.*?
—— tenuis, *Portl.*?
Climacograpsus scalaris, *His.*
Orthoceras, sp. (same as the Cefn-Hendre shell).

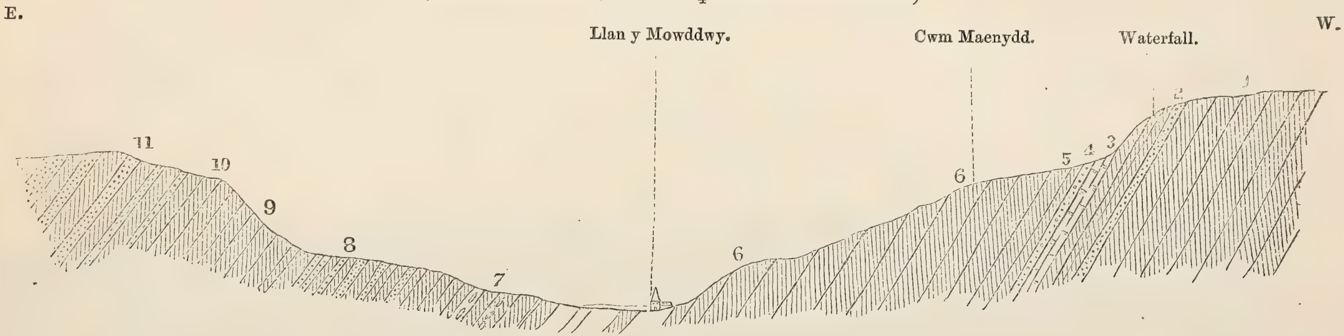
The Cardigan District.—The pale felspathic grits and black slates of Newport Bay and Cardigan, hitherto placed in the Lower Llandovery series "*b* 4," are not of this age, but belong to the Middle Bala or Caradoc Group ; as to this the fossil evidence is conclusive. Above these come rolling beds of pale slates and shales, then darker shaly slates, with a zone of pale felspathic grits ; these also I refer to the Bala period. The overlying shaly slates and rab are passage-beds of Caradoc-Llandovery age, presenting the gradual incoming of the Aberystwyth grits.

Reviewing the several rock-groups and their distribution, we find :—

(A) The Plynlimmon grits, seen upon Plynlimmon and around Rhyader, also probably in the hills west of Tregaron and Lampeter ;

Fig. 7.—*Section through the Dovey Valley at Llan y Mowddwy.*

(Horizontal scale, about $2\frac{3}{4}$ inches to the mile.)



1. Dark slates (Lower Bala).
2. Bala ash-bed.
3. Bala limestone.
4. Bala phosphate-bed.
5. Calcareous slates and flaggy shales.
6. Imperfect slates, dark shaly and rubbly slates and shales.
7. Dark-coloured irregular slates, with "cone-in-cone" nodules.
8. Grits, dark shaly slates, and rab. Fossils (Lower Llandovery).
9. Hard pale slates, banded slates, well cleaved (Tarannon group).
10. Dark rab and coarse gritty rab, and grit bands (Passage-beds).
11. Denbighshire grits, with dark rab and slates.

but they die out to the north and south of these localities. No fossils have yet been detected in this series in Cardiganshire, except, perhaps, in the boulder-block at Gogerddan, near Aberystwyth. Stratigraphically they lie above the Metalliferous slates; and these latter are proved, in the Llanbrynmaer, Dovey, and other areas, to be inferior to the Tarannon shales. Therefore, with reference to the Noedd Grug section, they must either represent the uppermost part of the Llandovery rocks or a special gritty development in the Tarannon shales. I adopt the latter view for the following reasons:—because of (1) their dissimilarity to the grits (Llandovery grits) which underlie the Tarannon shales at Llanbrynmaer, Llan y Mowddwy, and elsewhere; (2) their association with pale slate rocks similar to the Tarannon shales of the Corwen area; and (3) the occurrence of such a group of rocks, the Gala grits*, in this position in the south of Scotland. Moreover, in the Tarannon district the first appearance of such a development of grits in the Tarannon shale is already seen in the numerous thin grits, with contorted structure, of Tarannon Hill, Llanbrynmaer. The Rhyader pale slates thus appear also to belong to the true pale slate or Tarannon-shale series.

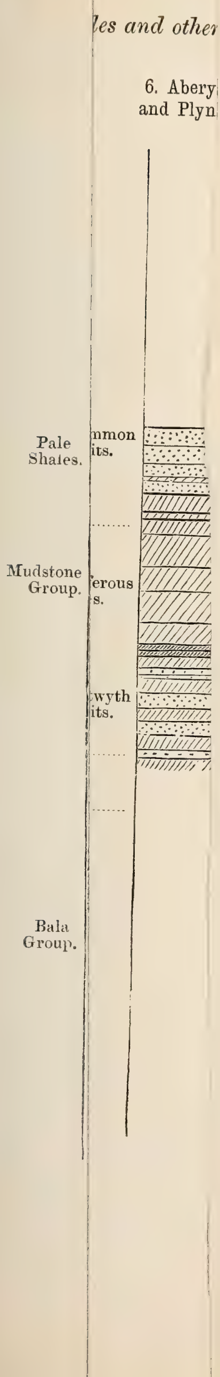
(B) The Metalliferous slates, which are enormously developed, spreading over a very wide area of Mid Wales. They maintain one general lithological character of hard, pale, shaly slates, also containing a zone of pale slates. The group is generally plumbiferous.

(C) The Aberystwyth grits may be taken as an arenaceous development of the Metalliferous slates, in its lower part. Like the Plynlimmon grits they die out to the north and south, their southerly attenuation being well exhibited around Llangrannog. They dip persistently under the Metalliferous slates; and the truth of this dip is proved by the position of the contorted raised structures upon the *under* surfaces of the grits†.

In the Dovey valley the Aberystwyth Grits are *represented* by gritty beds of a similar character; but here they appear to belong to a slightly different horizon, namely to the upper part of the Metalliferous slates; and the same is true of the grits exposed in the deep Talerddig cutting, Llanbrynmaer. The grits and conglomerates of Talieris, west of Llandeilo, very probably belong to the horizon of the Aberystwyth beds. In the Noedd-Grug section these beds, together with the Metalliferous slate, are represented by the Llandovery group of the Geological Survey, probably the Upper and part of the Lower Llandovery; but from the fossil evidence we cannot recognize the lowest part of the Llandovery Group (Lower Birkhill) in Central or West Cardiganshire. Part of the lower set of slates beneath the grits, described in the Cardigan and Dovey areas,

* Mr. Lapworth, F.G.S., writes me that "all the palæontological affinities of the Gala beds are with the Tarannon shales, with which, and not with the Upper Birkhill beds, they must eventually be connected."

† I have confirmed this test by examining the beds of Lingula-flags, Tremadoc and Bala rocks of South Wales, where these curious worm-like, fucoidal, and irregular prominences are found uniformly upon the *under* surfaces of the grits.


les and other
6. Abery
and Plyn
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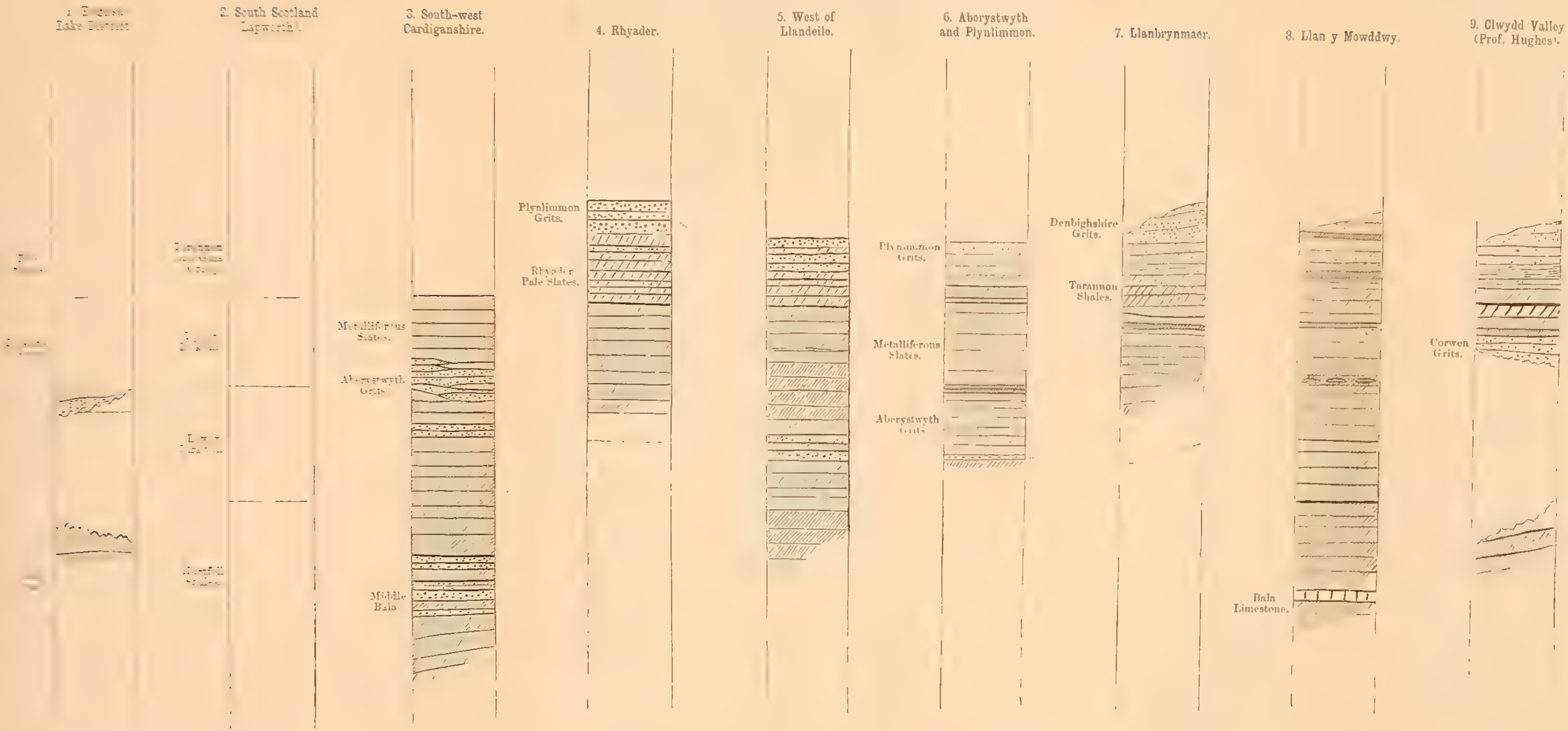
Comparative Vertical Sections of Silurian Rocks in Central Wales and other Localities.



probably belong here and complete the series; for we have seen there is no break of continuity down into the Bala formation.

PART III. *Palæontological Evidence.*

Although the order of succession of the forms of life have in all cases been first determined from the results of stratigraphical research, yet, that order once established, the organic remains, as considered in groups, become the supreme test of the age and relative order of rock-masses—superseding, and in some cases actually overthrowing, the apparent evidence of succession in the rock-beds. Such we find to be the case over a large area of Cardiganshire, where, as in the section from Aberystwyth to the Devil's Bridge, the stratigraphical series, seeming to be continuously ascending through some three or four miles of thickness to higher and higher beds, is proved by a handful of Graptolites to be radically misleading; for, the fossils being identical at almost the extreme ends of the section, the true reading is shown to be a series of inversions, by which the original order of the beds is obscured. Thus, over a large part of Mid Wales, it is to the organic remains alone that we can look with confidence for unravelling the apparently inextricable, and often delusive, tanglement of the strata, and establishing their true succession.

The most important element in our palæontological evidence is the group of Graptolites, these fossils having now become, through the most successful work of Mr. C. Lapworth, F.G.S., of the highest value in Cambrian and Silurian geology. All my work in this branch of study is based upon the published results of that geologist; and I am also particularly indebted to him for examining many of my Graptolites, as indicated in the Table (p. 170), and for valuable notes upon them conveyed to me in letters, from which I have quoted below.

A study of the Table brings out a number of important facts. At the first glance it is clear that all our fossil lists exhibit one and the same general geological fauna. Our richest localities are Cwm Symlog (eight or nine miles east of Aberystwyth) and Morben (near Machynlleth), also Cefn Hendre, Cwm, and Bryn y Carnau (in the neighbourhood of Aberystwyth). A single one of these localities (Cwm Symlog) yields every species, except four, of the true Graptolites known in Cardiganshire; and this, together with the intimately allied fauna of Morben Quarry, includes all our species except one (*Monograptus turriculatus*).

The other forms of life show no less clearly the unity of our fossiliferous Cardiganshire rocks. The *Orthoceras* is wide-spread in the Metalliferous Slates, and occurs also amidst the Greywacke-Flags of Cefn Hendre; and the various forms of Algæ and worm-trails are also characteristic of the whole range of the Cardiganshire group.

For the typical area of reference for Graptolitic deposits we must unquestionably look to the rich beds in the south of Scotland, of Llandeilo to Wenlock age, which have been so thoroughly worked out by Mr. Lapworth. And here the reading is decisive: our Cardiganshire series belongs not to the Glenkiln (Llandeilo) or the Hartfell (Bala) periods, when the *Didymograpti* and *Diplograpti* flourished, but to that part of the newer or Silurian era when the Monograptidæ were predominant, and in their greatest development, namely the Llandovery period (Birkhill Shales).

The more detailed affinities of our fauna will appear by a study of the last five columns of the "Table of Distribution." Every one of our species of true Graptolitidæ (excluding the Cladophora) occurs in the Upper Birkhill beds of Scotland. Eight species are common to the Lower Birkhill Shales, and nine (as also two species of Cladophora) to the overlying Gala and Tarannon groups.

Of the fossils of the two principal Graptolitic localities, Cwm Symlog and Morben, Mr. Lapworth writes that they "lie within the same general Graptolitic zone." . . . "Of the nine species recognized in the slates of Morben, five (namely *Rastrites maximus*, Carr., *Monograptus spinigerus*, Nich., *M. distans*, Portl., *M. Hisingeri*, Carr., and *Diplograpsus Hughesii*, Nich.) make their first appearance in the Upper Birkhill Shales of S. Scotland. *Rastrites maximus* is confined to the highest zone of that formation, in the Moffat area, and, together with its common associate, *Dipl. Hughesii*, seems to have become extinct before the deposition of the overlying beds of the Gala group.

"The second fossil locality (Cwm Symlog) is even more strikingly marked by its Upper Birkhill Graptolites. Sixteen forms have been identified from this spot. Of these, seven species (viz. *Monograptus crenularis*, Lapw., *M. intermedius*, Carr., *M. Clingani*, Carr., *M. runcinatus*, Lapw., *M. Hisingeri*, Carr., *Dipl. Hughesii*, Nich., and *D. sinuatus*, Nich.) are forms which are known for the first time in the Upper Birkhill of S. Scotland, and its equivalents in Girvan, Ireland, and the north of England. *M. intermedius*, *M. runcinatus*, and *M. crenularis* are peculiar to the Upper Birkhill, as also is *M. Clingani*, which is confined to a small seam in the very centre of the Birkhill beds."

Of the nine species of true Graptolites common to our Mid-Wales rocks and the Gala and Tarannon, not one is a special Tarannon form. *Monograptus turriculatus*, however, is most frequent in those beds; and the two species of Cladophora *Dictyonema venustum*, Lapw., and *Rhizograptus ramosus*, Lapw., are only known, elsewhere, in the Gala group (Scotland).

From the fossil evidence, therefore, there can be no hesitation in referring our Mid-Wales rocks to the same age as the Upper Birkhill of Scotland; and beyond the occurrence of the three species just mentioned in the rocks of the Devil's Bridge, there is nothing that conveys the slightest hint that any of our strata are newer than Upper Birkhill.

Lake District.—Fifteen of the Mid-Wales Graptolites are known from the Coniston or Graptolitic Mudstones of the Lake District; so that, in Mr. Lapworth's words, "the general facies of this Mid-Wales fauna is distinctly that of the Coniston Mudstones." These species are nearly equally distributed in the two zones (*tenuis*- and *argenteus*-zones) of that area. Also, amongst the other fossils, Mr. Marr recognizes the fragment (tail) of a *Phacops,* found by him at the Devil's Bridge, as a new species also occurring in the "Mudstones" of the Lake District.

Lithologically we find some of the Graptolite-bearing beds not unlike part of the Coniston Mudstone series; and some paler shales and slates, associated with the Graptolite beds at Morben, Machynlleth, and occurring again at Cwm Symlog, have their representatives also in the same series. Still, regarding them as a whole, our Cardiganshire rocks decidedly do not resemble their representatives in the English lake country.

We have seen that our various fossil lists indicate that all the fossiliferous beds belong to one general horizon. Certain minor differences, however, are to be observed, of which the most important are the presence of *Monograptus turriculatus* at Cefn Hendre and the Devil's Bridge, and the species of *Cladograpti* of the latter place, which are common to the Gala group of Scotland.

From the Graptolitic evidence Mr. Lapworth would arrange the beds in the following order:—

D. The *M. turriculatus* beds of the Devil's Bridge.
C. Next below (or perhaps identical with (D)) the Cefn Hendre grits.
B. Then comes the rich Graptolitic zone of Morben and Cwm Symlog.
A. Lowest of all lie jointly the *Diplograpsus* beds of Taren y Gesail, Corris, and Steddfa Gurig.

It will, however, be seen that this order does not correspond with our well-established succession of the greater groups as given in the first pages of this paper; for it would make our Metalliferous slates newer than the Aberystwyth grits. Now, with all my general confidence in fossil evidence, I consider that the palæontological data are here insufficient to maintain this order against the very strong stratigraphical evidence to the contrary. The principal fact is the occurrence of a single species (*Monograptus turriculatus*) in certain localities; and this *does* occur, only less commonly, in the Birkhill shales as well as the Gala group. Moreover the similar (more arenaceous) physical conditions common to our Devil's-Bridge bed and the Gala group may have to do with their having some fossils in common.

Mr. Lapworth's researches have established the fact that, in the Silurian and Cambrian periods, zones of Graptolites characterize definite stages, just as do the Ammonites in the Jurassic rocks. But these latter have their exceptions, and the minor zones are only trustworthy within local limits; much more so should we expect this to be the case with the more lowly organized group of Graptolitidæ. The occurrence of *Monogr. colonus* with Birkhill species in N. Wales is, indeed, an example of such. On the other hand the stratigraphical succession of the Metalliferous slates over the Aberystwyth grits is clearly marked over a large area, extending from near Borth, through Aberystwyth, and southwards to Llangrannog *, a gradual transition between the two groups being everywhere seen. And that the rocks here occupy their original relative positions is proved by the position of the raised rock-markings, which are uniformly found upon the *under* surfaces, as is normal in the lower palæozoic rocks, whereas when the beds are inverted these structures are found upon the *upper* surface.

The only plan of exact harmonization would be, it seems to me, to suppose that the Aberystwyth grits had died out to the east before we reach the fossiliferous beds of Morben and Cwm Symlog, and older beds had been somehow brought up in the confusion of folds and synclinals. This may be considered possible; but it again increases our difficulties in the eastern area (Devil's Bridge &c.), where the usual order of the strata persists. I therefore adhere to my original classification as given in the earlier pages of this work; for, indeed, the palæontological difficulty is very insignificant.

Comparing the faunas of the Aberystwyth grits and Metalliferous slates, we find that these do not afford any important data for their separation, but rather demonstrate their intimate connexion. Twelve of our species of Graptolites are known only from the Metalliferous slates—namely *Rastrites maximus*, *R. peregrinus*, *Monograptus spinigerus*, *cyphus*, *gregarius*, *intermedius*, *runcinatus*, and *involutus*, and all the *Diplograpti*: but this signifies probably little more than the less favourable conditions for Graptolitic life in the Aberystwyth grits; for the two rock-groups are bound together by the common possession of *Monograptus distans*, *Clingani*, *Sedgewickii*, *crenularis*, *spiralis*, *lobiferus*, *Hisingeri*, and *tenuis*, and *Climacograpsus scalaris*. The *Orthoceras*, *Nereites*, Fan-Algæ (*Buthotrephis*), and *Nematolites* (?) *tubularis* are also common to the two groups, and serve further to demonstrate the palæontological unity of the Aberystwyth and Metalliferous series.

But there is another group (the Plynlimmon group) whose exact age has not yet been fully considered. These beds contain no fossil evidence in themselves; but still, from their relations to the underlying metalliferous slates and to the more eastern sections, there is little room for hesitation as to their stratigraphical position.

The underlying rocks are shown to belong to the highest part of the Lower Llandovery group, or Upper Birkhill series, some of the species being actually of Gala types. Paralleling, then, our rocks with those of the south of Scotland, this overlying group of grits must either be close upon or actually in the Gala and Tarannon group. We have already seen how the stratigraphical and lithological considerations support the view that they really are an arenaceous development of the lower part of the Tarannon shale, thus being the true representatives of the Gala group of Scotland. The associated pale slates of Plynlimmon and around Rhyader (Rhyader pale

* There is a difficulty, as before mentioned, at Aberaeron, which I have not been able thoroughly to investigate.

slates) thus fall into line with the great pale-slate group of Britain —the Tarannon group.

N.E. Wales.—The Silurian rocks of Corwen, Llangollen, and the Vale of Clwydd have been described by Prof. T. M'K. Hughes *; and fossils have been collected from the Tarannon shales of the Conway area by Mr. C. Lapworth, F.G.S. Those species which are common to our Cardigan rocks are indicated in the Table; but, besides these, other species, characteristic of newer groups, are found—namely *Retiolites*, and *Monograptus priodon*, *colonus*, and *galaensis*. From these fossils Mr. Lapworth concludes that the Conway beds "correspond with the earlier portion of the Gala beds" of Scotland †. Thus the results of palæontology correspond well with the stratigraphical evidences, which show, in my opinion, that the great mass of our Cardiganshire series is unrepresented in the N.E. of Wales (as in the English border counties), or rather that it is represented by the break which Professor Hughes has worked out in that district at the base of his Corwen Grit. The black bands in the Clwydd valley, from which Prof. Hughes obtained Graptolites, do appear to lie in the parallel of the higher part of our Metalliferous group.

My friend Mr. J. E. Marr has just published the details of the sections at Cerrig y Druidion, N. of Bala ‡. He there finds beneath the Tarannon shales the equivalent of the Graptolitic mudstones, containing fossils of the same species as our Cardiganshire series, but also including *Monograptus colonus*, which is characteristic of much higher beds. The section appears to show a greater development of Graptolitic "mudstones" than in the Clwydd valley, and so far to represent more fully our Cardiganshire group; but here, again, as at Corwen, the series appears to be incomplete, because of the existence of the Silurian unconformity.

General Summary.

Central and West-central Wales is made up almost entirely of a great series of imperfect slates and Greywackes belonging to our Cardiganshire group, together with the overlying pale slates and grits of Rhyader and Plynlimmon. The Cardiganshire group is subdivided into the (1) Aberystwyth Grits, and (2) Metalliferous Slates; and part of the underlying slates may, perhaps, hereafter be proved to belong to the same group. Some minor subdivisions are also distinguishable. The arenaceous rocks are not constant over large areas, but die out both to north and south.

The rock-beds are astonishingly folded into violent contortions, with frequent inversions, especially in the Metalliferous series, so as often to produce the misleading appearance of a regular and continuous ascending series exceeding five miles in thickness. All the important axes of elevation in the country have a common N. and S. direction, two of the main folds being the Aberystwyth anticlinal

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 207, vol. xxxv. p. 694.
† Ann. Nat. Hist. 1880, vol. ix. p. 49.
‡ Quart. Journ. Geol. Soc. vol. xxxvi. p. 277.

and the Plynlimmon synclinal. Secondary axes of upheaval bring up the lower beds of the series at the Devil's Bridge and near Cwm Symlog. Innumerable minor foldings preserve the same north-and-south strike.

The included fossil remains, especially the Graptolites, prove the Aberystwyth Grits and Metalliferous Slates to belong to the same general geological horizon—namely, on the parallel of the upper Birkhill series of S. Scotland and the Coniston "Mudstones" of the English Lake district. The Plynlimmon Grits are probably an arenaceous development of the Tarannon Shales; and the Cwm-Elan conglomerates and Rhyader Pale Slates belong to the same series.

Following up our Cardiganshire series to the lines of junction with older and newer groups in parts of Montgomeryshire, South Cardiganshire, Caermarthenshire, and Merioneth, we find no evidence of a break in any part of the rock-groups; but there is concordant evidence of lithological passage from the Bala to the Llandovery groups, and from these upwards into the Tarannon Shales and the Denbighshire Grit series. On the contrary, in Denbighshire and N.E. Merioneth, Professor Hughes has shown that, just as in the English-Welsh border districts, there is an important stratigraphical break at about this Llandovery period. Now the beds below that break in N. Wales are the Bala group, *i. e.* inferior to our Cardiganshire series; those above it are basement-grits and conglomerates (the Corwen Grit), covered by the pale slates, with some black Graptolitic bands. These latter contain some species in common with the Cardiganshire group, but also others characteristic of a higher horizon than our fossiliferous beds.

Thus all the facts are harmonious in pointing to a continuity of the Silurian and Cambrian deposits in West and Central Wales, while an important break exists in the east and north-east. Our Cardiganshire group is only partially developed (its upper part) in the latter district, being, in fact, there represented by a great stratigraphical break—Sedgwick's original May-Hill unconformity.

I conclude that, while in the latest Cambrian times (Sedgw.) and the dawn of the Silurian era the elevatory forces, acting in a north-and-south direction, lifted up the sea-bed to form a land-surface over the west of England and the Welsh borders, these forces influenced the greater part of Wales only in a less degree—producing, it may be, the shallower water in which the Aberystwyth grits were laid down, but not interfering with the continuous deposition of sediment and the unbroken sequence of the geological record from the Cambrian to the Silurian eras.

Vales.

orth, F.G.S

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TABLE *showing Distribution of Fossils in Central Wales.*

Specimens marked thus (†) have been identified by Mr. C. Lapworth, F.G.S.

																						Scotland.		Coniston Mudstones.		
	Aberystwyth.	Devil's Bridge.	Parson's Bridge.	Cefn Hendre.	Bryn y Carnau.	Clarach Valley.	Morben Quarry, Machynlleth.	Cwm Symlog.	Llantrisant.	Llyfnant.	W. of Lisburne Mine.	Melin Newydd.	Lampeter.	Taren y Gesail.	Corys.	Dyffryn Castell.	Steddfa Gurig.	Tyn y Caunant, Dovey Valley.	Llanbrynmair.	Pennant Valley.	North Wales Pale Slates.	Lower Birkhill.	Upper Birkhill.	Penn[illegible]-zone.	Argenteus-zone.	Tarannon and Gala Group.
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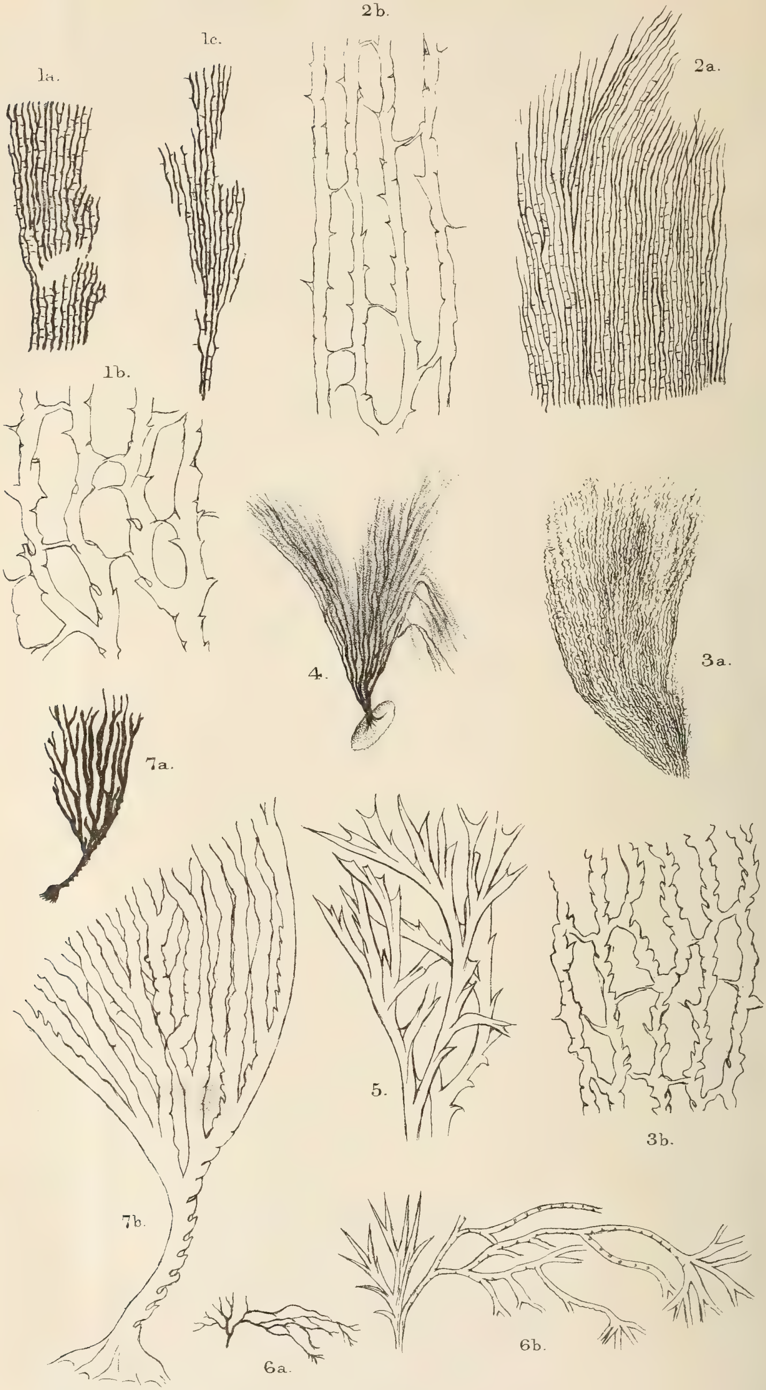
[1] Confined to the highest zone of the Upper Birkhill of South Scotland (*Lapw.*).
[2] P[illegible] to the Upper division of Birkhill Shale and its equivalents (*Lapw.*).
[3] Known only in Upper Birkhill beds of Moffat and Girvan (*Lapw.*).
[4] Restricted to a single zone in the Upper Birkhill Shales (*Lapw.*).
[5] A few fragments only in the highest seams of Upper Birkhill (*Lapw.*).
[6] *M.* [illegible] is peculiar to Upper Birkhill Shales (*Lapw.*).
[7] Makes its first appearance in middle of Upper Birkhill (*Lapw.*).
[8] *Diplograpsus Hughesii* is confined to the Upper Birkhill Shales (*Lapw.*).



A.S.Foord lith.

Mintern Bros. imp.

WELSH CLADOPHORA.

Appendix.

On the Cladophora (*Hopk.*) *or* Dendroid Graptolites *collected by Professor* Keeping *in the Llandovery Rocks of Mid Wales.* By Chas. Lapworth, Esq., F.G.S. &c.

[Plate VII.]

The forms of Cladophora collected by Professor Keeping from the Llandovery rocks of Cardiganshire are, regarded collectively, of a type almost new to British palæontology. Although intimately allied to the well-known dendroid species of the Quebec and Arenig formation, they are very distinct in their minor features. They are essentially of a Silurian (Upper) facies, and they remind us strongly of a group recently made known to us through the researches of Mr. Spencer, of Toronto, which characterizes the Clinton and Niagara Groups of New York and Upper Canada *.

None of our examples shows the complete polypary, or affords distinct proof of the presence of all the more minute classificatory features; but there is satisfactory evidence of the presence of at least four distinct genera and seven species. The genera represented are *Dictyonema*, Hall, *Calyptograptus*, Spencer, *Acanthograptus*, Spencer, and *Odontocaulis*, Lapw. *Dictyonema* is a well-known British genus; the remainder are new to British palæontology. *Calyptograptus* and *Acanthograptus* have been already briefly noticed from American strata by Mr. Spencer, but have not hitherto been figured. *Odontocaulis* is a new genus, of a peculiar type.

Of the seven distinct species recognizable, four (viz. *Dictyonema corrugatellum*, *Calyptograptus plumosus*, *C. digitatus*, and *Odontocaulis Keepingii*) are as yet peculiar to the Mid-Wales area. The remaining three have already been recognized by myself in the Silurian rocks of the south of Scotland. *Dictyonema venustum* certainly occurs in the Upper Gala group of Selkirkshire (Llandovery-Tarannon), and doubtfully in strata of a little older date in the Girvan area. *Dictyonema delicatulum* has been met with in the Llandovery (Lower) of Shalloch Forge, near Girvan. *Acanthograptus ramosus* occurs also in the Girvan area, at the base of the representative of the Tarannon Shales.

We do not yet know enough of the Cladophora of North America to enable us to identify any of these Mid-Wales forms with corresponding species already described or figured from the Silurian strata of that continent.

Genus Dictyonema.

Dictyonema, Hall, Palæontology, New York, vol. ii.

1. Dictyonema venustum, sp. nov. Plate VII. figs. 1*a*–1*c*.

Polypary cyathiform in the growing state, at least 10 inches in transverse diameter. Branches uniform, about one eightieth of an

* "Graptolites of the Niagara Formation," by J. W. Spencer, F.G.S., Canadian Naturalist, 1878–9, pp. 457–463.

inch in transverse diameter, radiating from the centre with few and remote bifurcations; approximately parallel distally; having 25 branches to the inch, connected by frequent capillary dissepiments 12 or 13 to the inch. Calycles biserial, closely adpressed to the polypary, 50 to the inch; apertural margin acute, rarely spinose.

The largest specimens obtained are distal fragments of the polypary, about two inches in length; and from the characteristics presented by these fragments the foregoing diagnosis has been drawn up.

This form is undoubtedly new to British palæontology. It may, however, be proved in the future to be identical with some of the imperfectly known American forms from the Clinton and Niagara groups.

Locality, Llandovery of Devil's Bridge, Aberystwyth. *Dictyonema venustum* is a rare fossil in the Llandovery rocks, of the south of Scotland, at Abbotsford, Winterhope, and Penwhapple Glen.

2. Dictyonema delicatulum, sp. nov. Plate VII. figs. 2*a*, 2*b*.

Polypary cyathiform? probably three or four inches in transverse diameter. Branches 40 to the inch, about $\frac{1}{120}$ of an inch in width, distally parallel, connected by indistinct capillary dissepiments 16 or 17 to the inch; bifurcations? Calycles biserial, 80 to the inch; aperture horizontal, devoid of ornament.

The best example of this species collected is shown in the figure, Plate VII. fig. 2*a*. The characters it presents show that it belonged to a distinct species from that already described, from which it differs mainly in the narrower and more closely-set branches, and in the more numerous calycles and dissepiments.

Horizon and Locality. Llandovery of Bryn y Carnau, Aberystwyth.

A single specimen has also been collected from the *Pentamerus*-beds of Shalloch Forge, Girvan, South Scotland.

3. Dictyonema corrugatellum, sp. nov. Plate VII. figs. 3*a*, 3*b*.

Polypary cyathiform, about one and a half inch in height. The branches are nearly parallel, about $\frac{1}{100}$ of an inch in diameter, and $\frac{1}{40}$ of an inch apart, connected by fine transverse dissepiments at regular distances of about $\frac{1}{20}$ of an inch, undulating in direction, the edges being thrown alternately from side to side by the projection of the outer margin of the calycles. Calycles 120 to the inch, alternate, with gibbous outer margin, and deep rounded aperture lying interior to the edge of the branch.

The most striking feature of this elegant little species is formed by the wrinkled or undulating outer edges of the branches, which wave from side to side owing to the projection of the ventral margin of the calycles. The slender branches divide more frequently than is the case with the generality of species of *Dictyonema*; and the transverse dissepiments are stouter and apparently polypiferous.

The calycles have their apertural margin strongly introverted, in the manner of those of *Dicellograptus*, Hopk.; and the line of the aperture lies wholly within the ventral margin of the branch.

Horizon and Locality. Llandovery of Devil's Bridge, Aberystwyth, Cardiganshire. Collection of Dr. Humpidge, Aberystwyth.

Genus Calyptograptus.

Calyptograptus, Spencer, Canadian Naturalist, 1878–79, p. 459.

"*Gen. char.* Polypary cyathiform, with numerous bifurcating branches, which are dichotomous at the termination, but are not connected by lateral processes. The branches are marked with striæ resembling rhomboidal pits; the axis has a black corneous exterior; and the radicle is composed of a thickened mass of the same texture as the branches. In appearance and texture this genus resembles *Dictyonema*; but the branches are all independent, not being connected by transverse dissepiments as in that genus, and are only united in one mass at the root" (Spencer, *loc. cit.*).

One of the Cladophora collected by Professor Keeping appears to possess many of the foregoing characters, which are given by Mr. Spencer as the peculiarities of his genus *Calyptograptus*. There are, however, some marked distinctions between our species and his typical examples; nevertheless it is most undoubtedly a closely allied form, and may therefore most conveniently be provisionally placed in this genus until we know more of the proper generic distinctions of these obscure fossils.

4. Calyptograptus? plumosus, sp. nov. Plate VII. fig. 4.

Polypary cyathiform?, in the growing state, about one inch and a half in height, composed of numerous bifurcating polypiferous branches united into a short stem, longitudinally striated, not connected by transverse dissepiments. Calycles closely arranged, biserial. Basal disk elliptical in form, about one fourth of an inch in diameter.

The stem, which is very short and stout, rises from the centre of the basal disk, and divides for the first time within about one eighth of an inch of its origin; the second, third, and fourth subdivisions are about one tenth of an inch apart; the later bifurcations are a little more remote. The primal branches are about one thirtieth of an inch in diameter; the final branchlets are almost capillary.

The substance of the polypary appears to have been somewhat membranous in character, and is wrinkled or striated longitudinally in the fossil. Two series of calycles are just discernible in the proximal portions of some of the branches, their apertural margins being exhibited as short slits crossing the branches transversely, almost at right angles to their general direction.

This form agrees with *Dictyonema* and *Callograptus* in the regular dichotomous nature of the method of subdivision of its principal branches. It differs, however, most markedly from both these genera in the apparent absence of the transverse dissepiments uniting the branches. In the mode of branching and in the form of the calycles it approaches the genus *Odontocaulis*, to be presently described, from which, however, it is easily separated by its short non-polypiferous stem.

Horizon and Locality. Llandovery of Devil's Bridge, Aberystwyth.

5. Calyptograptus? digitatus, sp. nov. Plate VII. figs. 6*a*–6*b*.

Polypary short, composed of numerous compound branches about $\frac{1}{100}$ of an inch in width, dividing irregularly, and terminated distally by a group of palmatifid branchlets about one tenth of an inch in length. Calycles of the type of those of *Callograptus*, about 50 to the inch.

The magnified drawing gives a fair idea of the external features of the only specimens seen, which are mere fragments. The proximal extremity of the stem is unknown; but the irregular mode of subdivision of the branches is different from what generally occurs in *Dictyonema* and its allies. There is a doubtful appearance of reticulation among the secondary branches.

The most remarkable feature of this form is the strange digitate character of the final spine-like branchlets. Mr. Spencer has noticed the same feature in the genus *Rhizograptus* (*op. cit. suprà*, p. 461), to which it is possible the present species properly belongs.

Horizon and Locality. Llandovery of Devil's Bridge, Aberystwyth.

Genus Acanthograptus, Spencer.

Gen. char. "Polypary shrublike, consisting of thick branches, principally rising from near the base, with little divergence and some bifurcations. One side of the branches is furnished with prominent spines or denticles, which appear to mark the cell-apertures. Test corneous and indistinctly striated."

"This generic form resembles *Dendrograptus*, but is stronger and more bushy than species of that genus, and has conspicuous spines indicating a different cell-structure" (Spencer, *op. cit.* p. 463).

The foregoing is Spencer's diagnosis of his new genus *Acanthograptus*. I have provisionally assigned to it one of Professor Keeping's species, which answers fairly enough to Spencer's definition. It is impossible to ascertain from Spencer's diagnosis whether the denticles that ornament the calycles are horizontal or inclined. If the former be the case, I suspect that *Acanthograptus* will be found to lie somewhere near *Thamnograptus* of Hall, in which the calycles are provided with long projecting spines, and that the present form must be regarded as the type of a new genus.

Acanthograptus occurs both in the Bala and Llandovery strata of Girvan, South Ayrshire, where, however, it is an uncommon fossil. None of the species collected by myself from the Scottish locality appears to be precisely identical with the Mid-Wales form.

6. Acanthograptus ramosus, sp. nov. Plate VII. fig. 5.

Polypary short, shrublike, with thick rigid branches, repeatedly and irregularly branching and rebranching. Base unknown. Calycles monoprionidian ?, often with long acute denticles, which have an ascending direction.

We have only one fair example of this genus from the Mid-Wales beds; and the foregoing characters are all that can be made out. The height of the visible portion of the polypary is less than half an inch. The main branches are apparently about one fortieth of an inch in diameter below, and are strongly striated throughout the whole of their extent. The right-hand branch, which is the better preserved, throws off three secondary branches in the upper half of its length. These secondary branches are of various lengths, being so extended that their outer terminations are on, or about, the same level. Each secondary branch splits at its summit into two secondary branchlets or polypiferous spines, about one twentieth of an inch in length, and terminating outwards in a short, stiff, mucronate point. The remaining primary branches present essentially the same general features.

One margin of the branches exhibits small denticulations at short and regular intervals (about 50 to the inch), marking the mouths of the calycles, the margins of which are usually concave. The outer angle of the aperture is sometimes very slightly projecting and more or less rounded off, as in the genus *Dictyonema*. Generally, however, the outer margin of the aperture is prolonged into a stout denticle, which stretches outward and upward at an angle of about 45 degrees to the main axis of the branch, and is terminated in a blunt point; the inner margin of the calycle, shown by a little groove upon the surface of the branch, running for some distance almost parallel with the outer margin.

The colour of the test is black, and the texture corneous.

Horizon and Locality. Llandovery of the Devil's Bridge, Aberystwyth.

ODONTOCAULIS, gen. nov.

Gen. char. Polypary cyathiform, composed of numerous independent and frequently bifurcating polypiferous branches, originating from the distal extremity of a short stem, which is likewise polypiferous, and is terminated proximally in an irregular corneous expansion. Hydrothecæ of the type of those of *Dictyonema*, biserial, subalternate.

The chief peculiarity of this genus is afforded by the character of the stem, which is identical in every respect with the main branches, and, like them, is denticulate or polypiferous throughout the whole of its extent. It commences proximally in a flattened expansion, with irregular or frayed-out edges, possibly the remains of a disk or bulb of attachment.

The mode of branching is rigidly dichotomous, the first two branches being formed by the subdivision of the main stem itself. Each arm branches and rebranches again and again in the same manner, at frequent and close intervals, composing an elegant cyathiform or fanlike polypary, very symmetrical in form. The branches retain their original width to their final division, which gives rise to two minute branches less than one tenth of an inch in length.

The hydrothecæ are more prominent than those upon *Dictyonema*. The distal extremity of each appears to have been free and slightly introverted, as in the majority of the bilateral family of the Dicranograptidæ.

Odontocaulis is separated from *Dictyonema* by the absence of the transverse dissepiments, and by the polypiferous character of the stem. From *Callograptus*, which it much resembles, the same features effectually distinguish it. In *Dendrograptus* the stem is stout and devoid of polypes, while the branches are irregularly disposed; in the present genus the stem is no thicker than the branches, is polypiferous, and the branches are regularly and symmetrically subdivided. It has probably its nearest ally in *Rhizograptus* (Spencer, 'Canadian Naturalist,' 1879, p. 460); but in that genus the stem appears to be barren, and the branches are possibly united at intervals.

7. Odontocaulis Keepingii, sp. nov. Plate VII. figs. 7*a*, 7*b*.

Polypary composed of numerous elegant flexuous branches, frequently divided and subdivided in a regularly dichotomous manner, originating from the distal extremity of a polypiferous stem about one fourth of an inch in length, and forming a cyathiform frond one inch and a half in height. Hydrothecæ 50 to the inch, free, distally patulous; aperture prolonged, introverted; denticle obtuse, rarely spinose.

In the only specimen collected the polypary commences proximally with a flattened expansion or disk with irregular or frayed-out edges. The stem is curved ventrally, and bears a single series of hydrothecæ, which are most distinctly shown. There are also indications of a second series. These hydrothecæ are a little more widely separated than those upon the branches, and appear to have been stronger and more projecting. At its summit the stem divides into two, originating the primary branches. Within one twentieth of an inch of their origin each of these again divides in a corresponding manner. Within the next tenth of an inch the branchlets are again subdivided, and so on till as many as six of these dichotomous divisions have been made. The terminal branchlets are very short, less than one tenth of an inch in length; but they are polypiferous to their visible extremities.

The hydrothecæ upon the branches average about 55 or 60 to the inch. The majority are seen as scaliform impressions; those visible in profile are not unlike those in *Dicellograptus*, Hopkinson.

The branches are of subequal diameter throughout, about one fortieth of an inch. They are quite free and independent, neither inosculating, as in some forms of *Dictyonema*, nor being connected by transverse dissepiments, as in that genus and its ally *Callograptus*.

This beautiful little species is dedicated to its discoverer, Professor Walter Keeping.

Horizon and Locality. Llandovery of Devil's Bridge, Aberystwyth, Cardiganshire.

EXPLANATION OF PLATE VII.

Fig. 1. *Dictyonema venustum*, sp. nov.: 1 *a*, natural size; 1 *b*, magnified 10 diameters. Locality: Devil's Bridge, Aberystwyth (coll. W. Keeping). 1 *c*, nat. size. Loc.: Williamshope, Gala group (coll. C. Lapworth).

2. *Dictyonema delicatulum*, sp. nov.: 2 *a*, nat. size; 2 *b*, magnified 10 diameters. Loc.: Bryn y Carnau (coll. W. Keeping).

3. *Dictyonema corrugatellum*, sp. nov.: 3 *a*, nat. size; 3 *b*, magnified 10 diameters. Loc.: Devil's Bridge (coll. Dr. Humpidge, Aberystwyth).

4. *Calyptograptus plumosus*, sp. nov.: nat. size. Loc.: Devil's Bridge (coll. W. Keeping).

5. *Acanthograptus ramosus*, sp. nov.: magnified 3 diameters. Loc.: Devil's Bridge (coll. W. Keeping).

6. *Calyptograptus digitatus*, sp. nov.: 6 *a*, nat. size; 6 *b*, magnified 5 diameters. Loc.: Devil's Bridge (coll. W. Keeping).

7. *Odontocaulis Keepingii*, gen. et sp. nov.: 7 *a*, nat. size; 7 *b*, basal portion magnified 5 diameters. Loc.: Devil's Bridge (coll. W. Keeping).

Discussion.

The President said that the paper was an important contribution to the geology of Mid Wales. The fossils were interesting and remarkable, especially the Graptolites.

Prof. Hughes pointed out that the North-Wales Silurian was quite different from that of South Wales, and that the area described by the author was far from the typical sections of either north or south and differed from both. He considered the paper a valuable contribution to our knowledge.

Dr. Hicks was glad to hear that in this area also, as in Pembrokeshire, there was no break between the Upper and Lower Silurians. It was also satisfactory to see that fossils had turned up on examination in these rocks, formerly reported to be barren or nearly so.

13. *Further* Notes *on the* Carboniferous Fenestellidæ. By George Wm. Shrubsole, Esq. F.G.S. (Read January 19, 1881.)

In a former communication to the Society I endeavoured to show that, as the result of a careful comparison of the existing individual forms, as figured by previous describers, with some tolerably perfect specimens in my own possession, it would be necessary to redescribe the species of *Fenestella* and considerably reduce their number. I accordingly append a redescription of the more prominent species; but before introducing that, it will be necessary to say something about the foundation of the genus *Fenestella*, since it can readily be imagined that the same causes which have thrown confusion into the species, have tended also to obscure the genus—namely the fragmentary and imperfect state of the specimens examined, and the want of attention to the stages of individual growth and other details. Accordingly I find the existing descriptions of the genus *Fenestella* inaccurate in many essential details. The genus has been defined by several palæontologists, but each time with reference to the fossils of a particular period; and no one description is sufficiently comprehensive to embrace all the members of the family Fenestellidæ as they occur in the various Palæozoic formations. A fresh description of the genus therefore appears to be desirable.

Without entering upon a full history of the genus *Fenestella*, I may mention that the first to describe it as such was Lonsdale, in 1839*, who adopted the name from the MS. of Miller of Bristol, who had been engaged on a work on the Corals of the Mountain Limestone, which he did not live to complete. He gave the name *Fenestella* to the lace corals. *Fenestella Milleri* of the Silurian is so named after him. Lonsdale twice defined the genus—first in the 'Silurian System,' and again in the 'Geology of Russia'†. In the former he restricted the cells to one row on each side of the keel; and in the latter he placed no such limit to the order or arrangement of the cells; hence it included *Polypora*, *Retepora* &c., in fact all the fenestrate species. His otherwise elaborate definition was also faulty to the serious extent that he described the appearance of a common incrusting coral as the mature growth of the *Fenestella*. This I explained in a recent communication to the Society.

Phillips next in order of time (1841) gave a very good description of the genus, so far as relates to the Devonian group‡; but much of its details are not applicable to the Silurian group.

Prof. M'Coy, in 1844§, restricted the genus to forms with two rows of pores on the branches, so as to include only the true *Fenestellæ*. The pore-cells he limits to the external face, whereas in the majority of the species they are on the inside of the polyzoary. He further

* Murchison's 'Silurian System,' p. 677.

† Geology of Russia, vol. i. Appendix A, p. 629.

‡ Palæozoic Fossils, pp. 22, 23.

§ M'Coy's Syn. Carb. Foss. Ireland, p. 200.

states that the perfect condition of *Fenestella* will be found in his genus *Hemitrypa*. This latter I have shown* to be a mistake due to an incrusting organism on *Fenestella membranacea*, Phil.

In his second definition, in 1854 †, which was intended to include both Carboniferous and Silurian species, M'Coy is more successful; no mention is made of the particular face on which the cells are placed. He does not adequately describe the shape of the polyzoary, and adopts one of Lonsdale's errors respecting a layer of vertical capillary tubes on the reverse face.

The last definition we have was by Prof. King ‡ in 1848, after arranging the Permian Polyzoa. He ignores M'Coy's work in 1844, and says that the genus, as constructed by Lonsdale in 1845, requires subdividing. As no trace of the incrusting coral was found in the Permian species, all reference to Lonsdale's supposed mature condition of the *Fenestella* is omitted. Prof. King's short and otherwise exact account is inexact in stating that the cells are distributed in two or more linear series. The true *Fenestellæ* have never more than two rows of cells on the interstice; the supposed row on the keel does not really consist of cell-pores, but of the bases of hollow spiny processes, which oftentimes, in the case of the Permian *Fenestellæ*, have been unduly distorted by a subsequent deposition of carbonate of lime.

From the foregoing it is evident that none of the original describers of the genus *Fenestella* has grasped the main features of it as a whole. What is wanted is a definition which shall embrace the whole of the Palæozoic *Fenestellæ*.

The following definition is therefore proposed, after a careful study of the several species ranging from Silurian to Carboniferous times.

Genus Fenestella, Lonsdale.

Polyzoary a calcareous reticulate expansion, either flat, conical, or cup-shaped, formed of slender bifurcating branches (interstices), poriferous on one face, connected by non-poriferous bars (dissepiments) forming an open network. *Cells* immersed in the interstices, and arranged in two longitudinal rows divided by a central keel, on which are often prominences. *Cell-mouth* small, circular, and prominent when preserved.

Fenestella plebeia, M'Coy, Syn. Carb. Foss. Ireland, p. 29, fig. 3.

Fenestella antiqua, Lonsd., M'Coy, Syn. Carb. Foss. Ireland, p. 200.

—— *carinata*, M'Coy, Syn. Carb. Foss. Ireland, pl. 28. fig. 12.

—— *devonica*, Semenow et v. Möller, Bull. de l'Acad. de St. Pétersbourg, t. vii. p. 233, pl. 3. fig. 16.

—— *formosa*, M'Coy, Syn. Carb. Foss. Ireland, pl. 29. fig. 2.

—— *flustriformis*, Phill. Geol. Yorkshire, pl. i. figs. 11, 12.

—— *fossula*, Lonsd., Darwin's Obs. on Volcan. Isl. p. 166.

* Quart. Journ. Geol. Soc. vol. xxxv. p. 282.

† Brit. Pal. Foss. p. 49.

‡ Permian Fossils. p. 34.

Fenestella fossula, Dana, Geol. U.S. Explor. Exped. p. 710, pl. ii. fig. 3.
—— *plebeia*, d'Orbigny, Prod. de Paléont. strat. t. i. p. 152.
—— *irregularis*, Phill. Geol. Yorkshire, pl. 1. figs. 21, 22.
—— *retiformis*, Schloth., King's Perm. Foss. pl. 2. figs. 8–19.
—— *trituberculata*, Prout, Trans. Acad. St. Louis, vol. i. p. 228.
—— *undulata*, Phill. Geol. Yorkshire, pl. i. figs. 16–18.
—— *virgosa*, Eichwald, Lethæa Rossica, tom. i. p. 358, pl. 23. fig. 9.
Gorgonia antiqua, Goldf. Pet. Germ. p. 99, pl. 36. figs. 3, *a,b*.

Sp. char.—*Polyzoary* a flat expansion, slightly convoluted, circular or oval in outline, depressed in the centre, by which it is attached. *Interstices* regular on the obverse face when well preserved, somewhat rounded otherwise, sides angular, keeled. *Dissepiments* thin, expanding at junction with interstice, more markedly on obverse than reverse face. *Fenestrules* regular, oblong, equal to width of interstice on obverse face, twice the width on reverse face; four in the space of two lines longitudinally, and six fenestrules in the space of two lines transversely. *Keel* rounded and strong, with two or three nodes in the length of a fenestrule. *Pores* round, prominent, their diameter apart, two or three in the length of a fenestrule, and often one more prominent than the rest in the angle formed by the junction of the dissepiment with the interstice.

Obs. This species, whether from Scotch, Irish, or English localities, is everywhere the predominant form of *Fenestella*. It attained to the largest expansion of polyzoary of any of the species. It deserves in every way to be regarded as the typical species of the Carboniferous varieties. I have traced its growth through all its stages, from a speck with two interstices on a stalk which clasped, it might be, the spine of a *Productus* or a fragment of *Serpula*, to the adult form with its strong and numerous rootlets. The early leaf-like growth on a footstalk soon underwent a change; the footstalk became one of many rootlets, and the polyzoary coralliform at the base, and ultimately a more or less circular expansion, the edges of which terminated in slightly convoluted lobes. Its attachment to the rock was secured by a cluster of rootlets from about the base, and, indeed, from any part of the polyzoary which offered convenience of attachment.

The actual size to which this species attains it is difficult to estimate, owing to the cleavage of the shale in which it occurs. I have seen indications which lead me to believe that an adult polyzoon might attain a diameter of nearly two feet. Specimens of this species will be found to differ from each other somewhat in appearance. This I have found is more owing to the nature of the matrix in which it has been imbedded than to any other cause. The more calcium carbonate present in it, the fuller and more life-like the organism appears, while it is flat and shrunken in the ordinary black aluminous shale of the Carboniferous beds.

In diagnosing the species the first thing to be noted is the size of its interstice, in which it is intermediate between *Fenestella nodulosa*, Phill., and *Fenestella polyporata*, Phill. There is also a peculiar smoothness and regularity, in the growth alike of interstice and dissepiment, which is attained by none of the other species and is a distinguishing mark. The presence of three or four pore-cells in a given space, the dissepiments, and the oblong fenestrules complete the identity. Prof. M'Coy's fine drawing of this species is taken from a partly worn-down specimen in which the sides of the interstice have become sharp and angular, and the keel scarcely visible; whereas the interstice should have been full and rounded, and capped with a ridge or keel, bearing the remains of spiny projections, while on either side the cells stood out prominent and free.

There is no doubt about the identity of this species with *Gorgonia antiqua*, Goldf., although his figure is drawn from a much weathered and mutilated fragment. It also agrees with *Fenestella retiformis*, Schloth., the leading Permian species. I am aware that a contrary opinion has been expressed. Virtually the species are the same. Phillips was, in this country, the first to give a descriptive account of it. His *Fenestella irregularis*, *F. undulata*, and *F. flustriformis* are all different portions of the polyzoary, under somewhat varying conditions of growth and preservation. I cannot agree with Prof. M'Coy in assigning *Fenestella flustriformis* to *Ptylopora flustriformis*. As figured by Phillips, it is only the cast in limestone of the reverse face; and, as such, its relationship to *Ptylopora* is purely conjectural. Prof. M'Coy was the first to recognize the importance of this species, and to do justice to it in the way of description; and hence, although not its author, that it should retain the name which he gave to it is generally conceded. In this view I am borne out by Prof. de Koninck, who states "that Lonsdale was the first to describe this species as *Fenestella fossula*, but that his description was incomplete, and insufficient to recognize it with certainty, whilst M'Coy's description was full and accurate"*. Phillips's notice of it some years prior to that of Lonsdale was even more incomplete. For the foreign synonyms of *Fenestella plebeia* I am also indebted to Prof. de Koninck's work on the Carboniferous Fossils of New South Wales.

Fenestella membranacea, Phil. Geol. Yorks. pl. i. figs. 1–6.

Fenestella flabellata, Phill. Geol. Yorks. pl. i. figs. 7–10.
—— *hemispherica*, M'Coy, Syn. Carb. Foss. Irel. pl. xxix. fig. 4.
—— *Shumardii*, Prout, Trans. Acad. St. Louis, p. 232.
—— *tenuifila*, Phill. Geol. Yorks. pl. i. figs. 23, 24, 25.

Sp. char.—Base cylindrical, tapering to a fine point, with strong non-poriferous rootlets attached. Upper part widely expanded. From nine to twelve inches in length, and five to eight inches in width. *Interstices* rounded, straight, in parallel lines, keeled. *Dissepiments* fine, slightly expanded at junction with interstice. *Fenestrules* oblong, slightly wider than insterstice, from two to three times as long as wide. At one inch from base, five dissepiments in the space of two lines measured vertically, and eight dissepiments in

* Foss. Pal. Nouv. Galles du Sud, 1877.

two lines transversely. Fenestrules gradually increasing in size with the growth. *Pores* small, round, more than their own diameter apart, placed on the outer face of the polyzoarium. At the base three pores within the length of a fenestrule; in the upper portion four in the same space.

Obs. There are many points of considerable interest attaching to this species. In shape and appearance it is an enlarged type of the Silurian species generally, and particularly of my *Fenestella lineata.* It is the only representative of the old type which has survived to Carboniferous times. In addition to its shape, it has most of the features of its prototype, viz. interstices seldom bifurcating, proceeding in parallel lines, and pores on outer face of polyzoary. Its early growth, from a minute point, was a tapering, often curved root-base, from which grew a hollow and gradually widening cone, which ultimately expanded in slightly folded and lobed outlines around the aperture. To secure in position so fragile a structure, numerous solid rootlets grew from various points of the base, and attached themselves to surrounding objects. Being somewhat cylindrical, it did not need to make the usual amount of lateral growth by bifurcation, as in the ordinary open type of Carboniferous *Fenestellæ.* Owing to this comparative absence of bifurcation in the insterstice, its lines are singularly regular, forming a series of parallel rows. Further, its lateral growth was obtained by a gradual enlargement of all parts of the structure, proceeding from the base upwards—so much so that while at the base four fenestrules may be counted in one line, at the distance of two inches there are only two in the same space, thus doubling the circumference of the polyzoary without the aid of division of the interstice. This enlargement in the growth is more or less persistent throughout the polyzoarium, but not to the same extent, and furnishes at once a key to the synonyms. Accompanying the increased growth, an additional pore-cell may be noticed between the dessepiments. Thus the difference between the base and the upper portion, both as to size and shape, is of a very marked character, and quite accounts for the several species into which this one has been divided. Phillips was the earliest worker at it; he named the extreme base *Fenestella membranacea*, the upper and enlarged growth *Fenestella flabellata*, and the more delicately formed and intermediate portion *Fenestella tenuifila.*

I have alluded to the fact that in the more cylindrical portion of *F. membranacea* bifurcation of the insterstice was arrested in part. At times a variety of circumstances may have hindered the longitudinal extension of the polyzoary; then we find a rapid bifurcation which gives a globose outline to the expansion, and the form is then the *F. hemispherica* of M'Coy, while all its other details as to the pores, interstices, &c. clearly point to its identity with *F. membranacea*, Phill.

The only species likely to be confounded with the foregoing is the *F. nodulosa* of Phillips. The square form of the fenestrule in the latter will at once indicate its character.

Locality. This species is comparatively rare in the Mountain-Limestone beds of England and Scotland, and very abundant in certain localities in Ireland.

FENESTELLA NODULOSA, Phill. Geol. Yorks. pl. i. figs. 31, 32, 33.

Fenestella bicellulata, R. Eth., Jun., Mem. Geol. Surv. Scotl. Sheet 23, p. 101.
—— *frutex*, M'Coy, Syn. Carb. Foss. Ireland, pl. xviii. fig. 10.
—— *Popeana*, Prout, Trans. Acad. St. Louis, p. 229.
—— *subretiformis*, Prout, Trans. Acad. St. Louis, p. 233.

Sp. char.—*Polyzoarium*, early growth foliaceous, having a distinct stem or footstalk, becoming an oval or circular expansion. *Interstices* regular, rounded, carinated and bifurcating; remains of spiny processes along the keel. *Dissepiments* thin, rounded, regular, a little arched in the early stage, not so thick as interstices. *Fenestrules* square, regular in the early growth, four fenestrules in the space of one line measured longitudinally, and four fenestrules in the same space measured transversely. In the later and upper growth there are three fenestrules only each way in the same measurements. *Cells* small, round, their diameter apart, one commonly at the end of each dissepiment, and one between, or three to each fenestrule: this is in the early growth; the later growth has four in the same space. When the cells occur in the angle formed by the junction of dissepiment with insterstice, the former is expanded at the point. This feature is not constant. Cell-mouth, when preserved, nearly on a level with the keel.

Obs. This is a very marked and easily recognized species; its square fenestrules and the round-wire-like nature of the interstices and dissepiments on the reverse face at once distinguish it from all others. In mature specimens the reverse has a peculiar and characteristic nodular aspect. In size it is somewhat minute, being intermediate between *Fenestella membranacea*, Phil., and *Fenestella plebeia*, M'Coy. Both Phillips and Prof. M'Coy were unfortunate in the fragments which they selected for description; it is not surprising, therefore, that when a good representative specimen was found it should be described as a new species. Hence by far the best description of *Fenestella nodulosa*, Phill., is that given for *Fenestella bicellulata*, R. Ether., jun.

In 1874 Dr. Young and Mr. John Young announced the discovery of a new Carboniferous polyzoon, *Actinostoma fenestratum*, in which we have all the characters hitherto observed by Phillips, Prof. M'Coy, and Mr. R. Etheridge, Jun., in *Fenestella nodulosa*, with the addition of the cell-aperture terminating in a nipple-shaped projection, the orifice of which was furnished with eight radiate denticles. To regard *Actinostoma* as the full development of *F. nodulosa* seemed the right course: as such I alluded to it in my former paper on the Carboniferous Fenestellidæ. Since then Mr. G. R. Vine, a most accurate observer of the palæozoic polyzoa, informs me that he has noticed the denticulate cell-aperture in *Fenestella plebeia*, M'Coy; while recently Mr. John Young, F.G.S., in a paper read before the Glasgow Natural-History Society, mentions the occurrence of the same in *Fenestella tenuifila*, Phill. Thus we have the record of this peculiar cell-aperture in two if not three species of *Fenestella*. Notwithstanding this evidence in favour of the denticulate aperture in *Fenestella*, I now hesitate to give this feature wholly or in part to it, since I made the discovery that some of the species of *Glauconome* possessed a fenestration not very dissimilar to that of *Fenestella*, and might easily, in a fragmentary condition, be mistaken for it, indeed have been so. There is no doubt about the fact that some of the species of *Glauconome* have the denticulate cell-mouth in question—*Glauconome stellipora*, Young, for instance; on the other hand, it is not equally well established that the cell-mouth of *Fenestella* had the same characters. There is the possibility that some of the fragments of reputed *Fenestella* upon which the denticulate aperture was seen, may prove to have belonged to *Glauconome*. This discovery of the fenestrate polyzoary in *Glauconome* considerably complicates the question of the nature and relationship of the palæozoic Polyzoa; and it will require careful observation on the part of palæontologists to work out the distinctive characters of the several genera, and assign to the various species the right fenestration. The result will have an important bearing upon *Glauconome*, more than on *Fenestella*, since we know so little of the life-form of the former, whereas the latter is better understood. It may be that both *Glauconome* and *Fenestella* and kindred Polyzoa, possessed the denticulate aperture. It is so far certain, as regards *Glauconome*; it may ultimately prove to be true of *Fenestella*. But for the present I consider that *Glauconome* has absorbed the existing evidence of the peculiar cell-aperture in favour of its claims. The other problems remain to be worked out.

I will now allude to a connexion which has become apparent during this inquiry between *Fenestella nodulosa*, Phill., and *Palæocoryne*, a hydrozoan originally described by Prof. Martin Duncan and Mr. Jenkins from the Lower Limestone shales of Ayrshire. With regard to my facilities for observing *Palæocoryne*, I may remark that it was described * from specimens washed from the shale, a process necessarily destructive of many of its more delicate and distinctive features. All the specimens in my possession, on the contrary, are *in situ* on the shale or limestone in which they were found. Prof. Duncan, speaking of it, says that "usually they are attached by a dactylose pseudo-cellular base to the margins of the polyzoaria of *Fenestellæ*"†. My observations would lead me to limit the attachment of *Palæocoryne* to one species of *Fenestella*, viz. *Fenestella nodulosa*, and to the pore-face generally, rather than the margin of the polyzoarium. The frequency with which I noticed this association of *Palæocoryne* with *Fenestella nodulosa*, led me to go carefully over my collection, and ascertain definitely the particular species of *Fenestella* with which it was most frequently allied. The result was, that, out of ninety-seven specimens

* Explan. Sh. 23, Geol. Surv. Scotland, p. 96.
† Quart. Journ. Geol. Soc. vol. xxix. p. 413.

of *Palæocoryne*, eighty-five are either attached to the polypite-face of *Fenestella nodulosa* or associated with it, while twelve only are free and unattached. In no one instance is there a suspicion that the species is any other than the one mentioned. Similar evidence to this I get in another way. I have more than one hundred specimens of *F. nodulosa* from the shales of Halkin Mountain, but out of them not one example showing the poriferous face; all without exception present to view the reverse side. This I explain by supposing that, as it is on the poriferous face of *Fenestella* that *Palæocoryne* finds its seat, that face has in consequence held the more firmly of the two to the shale. This is really so; for the base of it may be detected by a slight bulging of the polyzoary of the *Fenestella*, and its presence demonstrated by removing a portion. There is no similar difficulty in obtaining the obverse face of the other species from the same beds; nor do the other species present the appearance on the reverse face which I have noticed in *F. nodulosa*. The concurrence of these two species may be accidental; but I scarcely think so; the extent of its occurrence is not in favour of that idea; so that I think we may conclude that we have good evidence that *Palæocoryne* in the upper beds of the Mountain Limestone is exclusively confined to the polyzoary of *Fenestella nodulosa*, Phill. I may mention that I have found *Palæocoryne* associated with *F. nodulosa* in the middle beds of the Mountain-Limestone series of North Wales, and also directly seated upon the poriferous face of the same from the Calciferous Sandstones of Scotland. I have previously pointed out that several inferior organisms are parasitic upon or incrust the polyzoaria of *Fenestella*, from Silurian times upwards—such as *Hemitrypa, Aulopora, Alveolites*, and *Diastopora*; and now *Palæocoryne* has to be added to the list. In the case of the previous incrustations there is no doubt that the parallel branches of the *Fenestella* afforded suitable base-lines for the attachment of the incrusting coral. Whether there was any thing more than this in the preference shown by *Palæocoryne*, is one of the problems to be worked out; and it will, I have no doubt, receive due attention at the hands of Prof. Martin Duncan, to whom I have handed over my specimens of *Palæocoryne* for further elucidation.

Fenestella polyporata, Phill. Geol. Yorks. pl. i. figs. 19, 20.

Fenestella multiporata, M'Coy, Syn. Carb. Foss. Irel. pl. xxviii. fig. 9.
—— *intermedia*, Prout, Trans. Acad. St. Louis, p. 231.
—— *variabilis*, Prout, Trans. Acad. St. Louis. p. 231.

Sp. char.—*Polyzoarium* foliaceous at first, arising from a stem, ultimately becoming a flat circular network. *Interstices* large, broad, rounded, keeled. Dissepiments thin, one third the thickness of the interstice, somewhat irregularly placed, not expanding at junction with interstice. *Fenestrules* large and elongated, three times as long as wide. Four fenestrules in the space of two lines measured transversely, and two fenestrules in the space of two lines longitudinally. *Keel* rounded and well developed, marked along its course with numerous spiny processes. *Pores* small and round, their own diameter apart, prominent when preserved, from five to nine in the length of a fenestrule.

Obs. This is the largest species of Carboniferous *Fenestella*, as regards the size of its interstice and fenestrules, although not so as to the ultimate growth of its polyzoary, which is considerably less than that of *F. plebeia*, M'Coy. This peculiarity at once distinguishes it from any other species. It is subject to considerable variation, and will be met with both larger and smaller than the one described. Prof. M'Coy, in his arrangement of the *Fenestellæ*, assigned the smaller type to Phillips's *F. polyporata*, and the type with the larger development and greater number of pores he described as *F. multiporata*; but as both conform so well to the type in other respects, there is no reason for this division. This species often, on the reverse, attains to the size and character of some of the *Polyporæ*, from which it may readily be known by having only a double row of pore-cells.

Fenestella polyporata never occurs very freely in any locality, but seems generally distributed throughout the Carboniferous strata.

FENESTELLA CRASSA, M'Coy, Syn. Carb. Foss. Irel. pl. xxix. fig. 1.

Fenestella laxa, Phill. Geol. Yorks. pl. i. figs. 26–30.

My previous notice of this species was limited to the extent of showing the identity in character between the species respectively described by Phillips and Prof. M'Coy as *Fenestella laxa* and *Fenestella crassa*. Since then a wider acquaintance with the Carboniferous Polyzoa, and more especially with the Irish species in my possession, has caused me to hesitate about including it among the *Fenestellæ*, since I have good reason for believing that the fragment which has been described as such will be ultimately found to belong to another fenestrate genus of Polyzoa. The original drawing of this species by Phillips clearly included two species of Polyzoa—one a *Polypora* with three rows, and the other apparently a *Fenestella* with two rows of pores—the latter from Ireland, be it remembered, where in certain localities *Ichthyorhachis Newenhamii*, M'Coy, and *Glauconome grandis*, M'Coy, are not uncommon.

Specimens in my possession lead me to say that I have little doubt of being able to show that the fenestrated form described as *Fenestella crassa*, M'Coy, is likely to prove to be the network or polyzoary of one or other of the above species, or some kindred form.

A glance at the drawings of *Fenestella crassa* given by Prof. M'Coy would seem to confirm this view. The coarseness of the interstice, and irregularity of the dissepiment and growth generally, are not characteristic of the Fenestellidæ. Its true affinities have yet to be ascertained. For the present it is enough to say that its claims to be considered a *Fenestella* are very doubtful.

Fenestella halkinensis, sp. nov.

Sp. char.—*Polyzoarium* a flat, oval, or circular expansion, foliaceous in its early growth, having a stem and expanded root-base. Interstices flat, broad, very slightly rounded, keeled, the sides often showing a flap or fringe. *Dissepiments* irregularly placed, very thin in early stage, gradually thickening, rarely more than one third of the thickness of the interstice. *Fenestrules* elongated, becoming oval with increased growth, four in the space of two lines measured longitudinally, and six in the same space transversely. *Pores* small, round, often twice their diameter apart, three in the length of a fenestrule, four and sometimes five in the later and larger growth. *Keel* a narrow round wavy line, having three nodes in the length of a fenestrule.

This species at first sight would seem to have a strong resemblance to *Fenestella plebeia*, which, however, is soon dispelled by careful scrutiny; for it will be found to possess scarcely a feature in common. Its broad flat interstices at once distinguish it from the round or more often angular stem of *F. plebeia*; while the greater distance between the cell-pores, and the thread-like nature of the keel, complete the distinction. Again, the growth of *F. plebeia* is noticeable for its regularity and smoothness, while *T. halkinensis* is by comparison coarse and irregular. The root-base of *F. plebeia* is secured in position by numerous rootlets; while *F. halkinensis* has a broad, expansive and adherent base, which is further strengthened by the interstices which, in favourable positions, directly adhere to the rock by a similar flat calcareous base. Its expansion was not only much smaller in size than that of *F. plebeia*, but the last details would seem to indicate a species of dissimilar habits, by attaching itself to rock-surfaces which the rootlets of *F. plebeia* would fail to enter. The affinities of this new species are, on the other hand, clearly with *Fenestella polyporata*, Phill., rather than with *F. plebeia*. It has very much the appearance of being a diminutive variety of *Fenestella polyporata*, especially on the obverse face.

Locality. Fairly abundant in the Cement-stone Quarries near Pen yr Wylfa, Halkin Mountain, North Wales.

It will be noticed that I have described only five species of Carboniferous *Fenestellæ*. I by no means wish it to be understood that I do not believe in the existence of species other than those I have described. Of these *F. plebeia*, M'Coy, *F. nodulosa*, Phill., *F. polyporata*, Phill., and *F. membranacea*, Phill., are really the principal and prevailing forms, and will be found in more or less abundance in association with other Polyzoa, from the Calciferous Sandstones of Scotland to the topmost beds of the Mountain-Limestone series of North Wales and elsewhere. The only partial exception to the rule is *Fenestella membranacea*, Phill., which is either absent or not so abundant at certain points and localities. Having proved the existence and association of these species at various horizons in the Carboniferous series, I speak confidently as to the fact that the leading species of the Carboniferous *Fenestellæ* are few in number, while the reputed species are made up from the mutilated and altered fragments of the polyzoarium in all stages of its growth, not only of *Fenestella*, but of *Ptylopora*, *Glauconome*, and *Ichthyorhachis*, all of which presented a reticulated character, which under certain conditions might have been (and, indeed, has been) mistaken for that of *Fenestella*. Hitherto it has been the practice to assign any free fenestrate fragment of a polyzoan to *Fenestella*. With the discovery to which I have alluded, that *Fenestella* was not singular in possessing a fenestrate polyzoary, the error of that method of determining polyzoan fragments becomes apparent.

The few species to which I have reduced the British Carboniferous Fenestellidæ is, I find, in perfect agreement with the results arrived at on the American continent. Prout has published * a list of eight species of *Fenestella* from the Carboniferous rocks of North America; although no plates are given, the details of the species are so minute as to leave nothing to be desired in the way of description. Of these eight species there is only one (*Fenestella Norwoodiana*) that has any claim to be considered a new species; they correspond exactly with the types of our various English species. Prout did his work without the aid of Prof. M'Coy's book on the Carboniferous Fossils of Ireland, in which the Fenestellidæ are for the first time adequately described. The result of Prout's independent research, apparently with ample material, is that only five good species are made out. These American synonyms I have placed for the first time under their respective English species.

There are possibly a local species or two of *Fenestella* which I have not described. *Fenestella halkinensis* is one of these local forms. I have not met with it elsewhere than at Halkin Mountain. These local species require to be very carefully worked out before they can be definitely pronounced to belong to the Fenestellidæ. I would suggest, with a view to the prevention of a needless multiplication of species of *Fenestella* in the future, that, before describing a new species, the nature of the attachment of the fenestration should be definitely ascertained, whether to a root-stalk with rootlets, as in *Fenestella*, or to a midrib or stem, as in *Ptylopora* and *Glauconome*. Nor do I consider this standard too high. I have adopted it with the five species which I have described. Owing to the complicated surroundings which I have shown to be connected with *Fenestella* and the forms allied to it, I am strongly of opinion that some such course of procedure is necessary.

The following table of the measurements of the leading features in the several *Fenestellæ* will be found of considerable service in establishing their identity.

* Trans. Acad. St. Louis, vol. i. p. 228–236.

Species.	Number of pores between dissepiments.	Shape of fenestrule.	Number of fenestrules in two lines transversely.	Number of fenestrules in two lines longitudinally.
Fenestella plebeia, M'Coy...	3–4	Oval.	6	4
—— *membranacea*, Phill....	3–4	Oblong.	8	5
—— *nodulosa*, Phill..........	3–4	Square.	6–8	6–8
—— *polyporata*, Phill.......	6–9	Elongate.	4	2
—— *halkinensis*, Shrubsole	3–4	Elongate.	6	4

Discussion.

The President stated that this group, which ranged from the Llandeilo to the Permian, is often represented by very imperfect specimens, and that there is great difficulty in discriminating the forms. Nowhere are they so well preserved as in the Carboniferous rocks of Flintshire and Scotland.

Dr. Murie spoke of the value of the method adopted by the author in studying the varieties of growth and development in each species.

Prof. Seeley regarded the principle on which the author had worked as a very sound one, and he thought that such revisions of certain life-groups were calculated to be of the greatest service to geology.

The President remarked upon the difficulty that arises from the fact that many type specimens are inaccessible for reference. He deprecated the creation of new specific names before a rigid comparison had been made with the old ones.

14. *On the* Coralliferous Series *of* Sind, *and its Connexion with the last* Upheaval *of the* Himalayas. By Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.L.S., &c. (Read February 2, 1881.)

Contents.

I. *Introduction &c.*

A memoir by Grant, illustrated by Sowerby, which appeared in the 'Transactions' of the Geological Society (series 2, vol. v. 1837), first brought the countries west and east of the Indus under the notice of European geologists. Fossils from Sind, Baluchistan, and Cutch were therein described; and the types were presented to the Society. But it is to Mr. Vicary that science owes the first attempt at a complete description of the geology of Sind *. Written in 1847, the fossils which should have illustrated his paper, and some others collected by Lieut. Blagrove in Cutch, were handed over to MM. d'Archiac and Jules Haime for examination and publication. Their fine work, the 'Description des Animaux Fossiles du groupe Nummulitique de l'Inde,' was published in 1852. They only recognized one geological horizon, the Nummulitic, although Grant had expressed an opinion that there was more than one fossiliferous series. Messrs. Cook and Carter added to the knowledge of the Baluchistan area in 1860 †; and the last-named naturalist felt it necessary to give a Miocene age to some fossils which Sowerby had figured for Grant. On the other hand, MM. d'Archiac and Jules Haime severely criticised M. d'Orbigny for stating that some of their Sindian species were of Falunian age, and decided against Dr. Carter's grouping of some of the marine Tertiary beds as Miocene ‡.

In 1863 Mr. Henry M. Jenkins, F.G.S., at that time Assistant-Secretary of this Society, and myself were endeavouring to learn something about Tertiary deposits situated as remotely as possible from European types.

A collection of Mollusca and Corals from Java had been sent to the Society by M. de Groot; and we proceeded to examine them; and in order to determine the affinities of some, which seemed to be of younger age than the Nummulitic, it became necessary to study the work of MM. d'Archiac and Haime on India and to examine their types.

We found that there was a species in Java which my friend called

* Quart. Journ. Geol. Soc. 1847, vol. iii. p. 334.

† Cook, Trans. Med. Phys. Soc. Bombay, vol. vi. pp. 1–45; Carter, Journ. Bombay Royal Asiatic Society, vol. vi. p. 184.

‡ See Carter, Geol. Papers on Western India, pp. 628–776, and the general *résumé* in their work already noticed.

Vicarya callosa, and that it was closely allied (the distinctions being only of ornament) to *Vicarya Verneuilii*, D'Arch., from Sind.

This *Vicarya* of Java was associated with species which are closely allied to those of the Miocene of Western and Eastern Europe.

A Coral (*Heliastræa Herklotzi*, Dunc.) from Java resembled the Miocene Heliastræans more than those of the Eocene*.

Following up the subject carefully, I examined all the collections submitted to MM. d'Archiac and Jules Haime; and to my surprise I found that they had neglected many specimens which had not only a Miocene but even a Pliocene facies. The identity of some species with members of the West-Indian Miocene Coral-fauna was tolerably evident; and whilst admitting the similarity of the mineral condition of all the fossils, I divided the genera into those which elsewhere are found in Eocene, Miocene, and Pliocene formations.

During the following year† I examined and described twenty-six species of Corals from Sind, from unknown geological horizons near Karáchi. Some had been previously described by D'Archiac and Haime; but the bulk had not. The evidence of the existence of three Tertiary deposits instead of one seemed overwhelming.

Subsequently the Geological Surveyors of India, Mr. W. T. Blanford, F.R.S., and Mr. Fedden, made an elaborate survey of Upper and Lower Sind, and Messrs. Wynne and Fedden of Cutch.

In the last-mentioned district fossils were found which proved the equivalency of the deposits with those of Sind, and that there was a higher Tertiary horizon than the Nummulitic.

The Corals collected in Sind by the Survey, under the superintendence of Messrs. Blanford and Fedden, and carefully marked with figures denoting their geological horizons, were sent to me by Mr. Medlicott, F.R.S., the present Superintendent of the Survey, so that they might be described in a volume of the 'Palæontologia Indica.'

But simple description was not all the requirement of the Survey and myself. Certain questions of great importance had arisen in the geology of India; and it was probable that the determination of the age of the coralliferous strata would assist in deciding the ages of the Himalayan upheaval, of the Siválik deposits, and of certain olive shales underlying a trap at the base of the Nummulitic series—questions which had been attempted and had been answered by Messrs. Medlicott, Blanford, and Lydekker, and which required some confirmatory evidence.

There was another reason why I should be honoured by the Geological Survey of India asking me to undertake the description of their splendid collection of fossil Corals from Sind. In my Presidential Address for the year 1878 I criticised the opinions of my friends Messrs. Medlicott and Blanford regarding the age of the Himalayas, and inferred that their decision regarding the Post-pliocene date of the so-called Nerbudda fauna, was influenced by the discovery of a human implement in the containing deposit.

They took the very philosophical course of affording me the means of converting myself to their opinions.

* Quart. Journ. Geol. Soc. vol. xx. p. 45.

† Ann. & Mag. Nat. Hist., April 1864 (Fossil Corals from Sind).

The description of the Corals has been published in a volume of the 'Palæontologia Indica;' and although the evidence regarding a Pliocene marine fauna failed, there is no doubt about the former existence of Lower and Middle Tertiary coralliferous deposits in Sind.

II. *The Stratigraphical Position of the Series and of the Ossiferous Manchhar Deposits.*

The detailed description of the geology of Western Sind is to be found in the Memoirs of the Geological Survey of India, vol. xvii. part 1 (1879), by W. T. Blanford, F.R.S. &c., Deputy Superintendent of the Geological Survey of India; and it is therefore only necessary to explain those parts of it which relate to the general succession of the stratigraphical series and the position of the strata yielding Corals.

The mountain-ranges west of the Indus run nearly north and south, in irregular parallel series. The longest range, the Khirthar, is slightly curved, the concavity being to the east; and it extends from slightly south of 26° N. lat. to close to 28° N. lat. The Laki range, more to the east, is nearly coincident with the sixty-eighth parallel of east longitude, and extends from the Indus north of 26° N. lat. to nearly a degree to the south. Other minor but nearly north-and-south ranges occur; and the whole were comprised by MM. d'Archiac and Haime under the title of the Hala range (a name unknown to the natives).

The following is the list of geological formations in Western Sind, and which are to be recognized in one or other of the mountain-ranges*:—

Group.	Subdivisions.	Approximate Thickness.	Age.	Remarks.
		feet.		
Alluvial	....	?	Post-Tertiary.	
Manchhar ...	Upper	5000	Pliocene	Unfossiliferous.
	Lower.........	3000–5000 ...	Old Pliocene or Upper Miocene.	Vertebrate remains.
Gáj	....	1000–1500 ...	Miocene	Coralliferous; no Nummulites.
Nari	Upper	4000–6000	.... (Oligocene.)	Unfossiliferous.
	Lower.........	100–1500	.... (Oligocene.)	Coralliferous, with *Nummulites garansensis*.
Khirthar ...	Upper	500–3000 ...	Nummulitic	Nummulitic limestone.
	Lower.........	6000?	....	Unfossiliferous.
Ranikot.........	....	2000	Lower Nummulitic.	Fossiliferous. Corals and Nummulites.
Trap	....	40–90	Deccan Trap.	
Cretaceous .	*Cardita Beaumonti* beds.	350–450	Transition beds ...	Fossiliferous.
	Sandstones ...	700	Cretaceous.	Horizon not determined.
	Limestones with Hippurites.	320.		

* From the Memoir by Blanford, p. 32, slightly modified.

Explanatory Sections.—In the Laki range, south-west of Amri on the Indus, are dark-coloured hills which contrast with the cliffs of grey and white Nummulitic limestone behind them. A section close to the hill called Barrah is given by W. T. Blanford, F.R.S.; and it shows that the range consists of three parallel ridges (see fig. 1, p. 194).

The outer, to the east, is composed of Tertiary rocks, while the intermediate one consists of Cretaceous beds faulted to the eastward against the Lower Eocene strata, and dipping under them to the westward.

This section shows the normal sequence of the groups of strata from the Cretaceous to the Khirthar inclusive. Above the Nummulitic limestone of this last group the Nari and Gáj series are wanting, and the Manchhar succeeds*.

On the Gáj river, in the Khirthar range, W. T. Blanford remarks that a thickness of at least 25,000 feet of strata is exposed (see fig. 2, p. 194). The succession from west to east is:—unfossiliferous strata, probably of Cretaceous age, followed by Khirthar strata (the Ranikot series, the lowest Eocene, being absent); then the lower and upper Nari series come in, and are followed by the Gáj and the Manchhar deposits.

The lowest coralliferous deposits occur in the soft olive shales and sandstones with volcanic ash, belonging to the *Cardita Beaumonti* series below the trap. The accompanying remains are those of Amphicœlian Crocodilia and Echinodermata; and the deposit was neither a reef-structure nor a deep-water one.

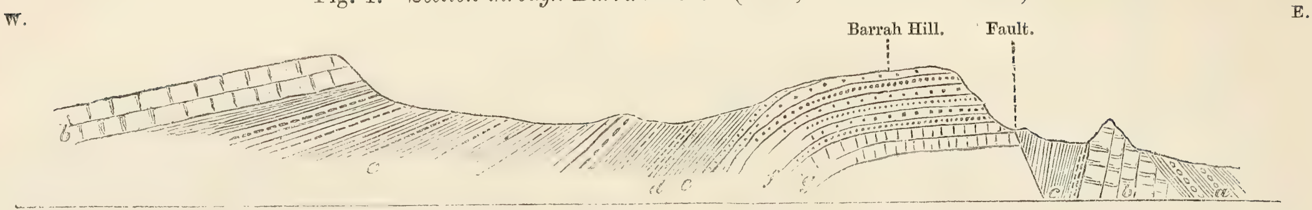
The lower part of the Ranikot series, resting immediately on the trap, consists of soft sandstones, shales, clays with gypsum and lignite, and pyritous shale. A few fragments of bones and some dicotyledonous leaves occur. These freshwater strata are succeeded by highly fossiliferous marine limestones, often brown in colour, interstratified with sandstones, shales, clays, and ferruginous bands.

Nummulites appear for the first time, and there is a grand development of Corals, Echinodermata, Gasteropoda, and Cephalopoda. It was not a very deep-water formation. Erosion of the surface of the Ranikot strata occurred before the deposition of the next series.

The Khirthar series includes in its highest portion a massive, pale or dark grey, hard, compact Nummulitic limestone whose extreme thickness is 3000 feet. It thins out to the south-west, and disappears within a distance of twenty-five miles of its greatest development. Other Nummulitic limestone-beds are found, which may be lower in the series; and they and the main group are represented elsewhere by shaly limestones and sandstones with calcareous bands. In some districts flint occurs in a limestone with *Alveolinæ*. The lower members of the series are often wanting, and are well represented by shales, marls, and sandstones and where these are present; unconformity with the underlying Ranikot beds is not seen; but where they are absent the Nummulitic limestone (as in the Laki range) rests unconformably. The compact limestone is of course

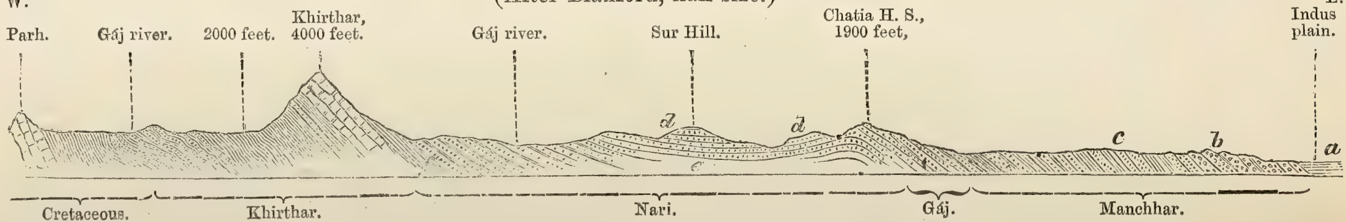
* Memoirs Geol. Survey of India, vol. xvii. pt. 1, p. 131.

Fig. 1.—*Section through Barrah Hill.* (Scale, 1 inch to 2500 feet.)



a, Manchhar strata, rest on pale clays of Khirthar age, with *Nummulites Leymeriei*, and then on Khirthar Nummulitic limestone, *b*, the beds dipping to the west. This limestone forms the eastern ridge. West of the ridge is some low ground, in which the upper members of the Ranikot group, *c*, crop out, also with a reversed dip. They end abruptly against a cliff of white and grey limestone, the boundary being a fault. This limestone, *g*, forms the base of the Barrah Hill, and contains Hippurites. A great thickness of sandstones, *f*, forms the top of the dark-coloured hills. On the top of the hills is a bed containing oysters and fragments of apparently reptilian bones. West of the hills are olive shales with *Cardita Beaumonti*, *e*. The trap, *d*, follows, and then the Ranikot group, *c*, which is of great thickness, and the Khirthar limestone, *b*.

Fig. 2.—*General diagrammatic Section of Khirthar Range, on the north bank of the Gáj River.* (After Blanford, half size.)



a, Indus plain; *b*, upper, *c*, lower Manchhars; *d*, Gáj; *e*, upper, and *f*, lower Nari.

highly fossiliferous; but it has not yielded very good specimens of Corals. The indications of a fringing-reef-building fauna, or a bank of coral, are distinct; but the species when compared with their modern analogues do not indicate a great reef-development. Amongst other fossils, Lamellibranchiata prevail, and the Echini are numerous; but the Nummulites and Orbitolites, *Alveolinæ*, and *Patellinæ* are the most important organic remains. Amongst the Nummulites there are *N. Ramondi*, *N. biaritzensis*, *N. Beaumonti*, *N. granulosus*, and *N. Leymeriei*.

The Nari series rests conformably on the Khirthars; and there is occasionally an apparent passage from the Khirthar limestone into a yellow or brown rock of the Nari group. There is, however, a biological break; for the Nummulites of the upper group are characteristic, and differ from those of the lower. The Khirthar forms are not found, and *Nummulites garansensis* appears with *Orbitoides papyracea*, in the Nari series. The rock is a limestone with intercalations of sandstones and shales. As a rule, shales, fine sandstones, and occasional bands of limestone form the base of the Nari group, and pass upwards into coarse, massive, thick-bedded sandstones, attaining a thickness of from 4000 to 5000 feet on the eastern flank of the Khirthar range.

A local break occurs to the south, and the Upper Nari beds rest unconformably on the denuded edges of the Lower Nari brown limestones; and still further south, fifty miles east of Karáchi, there is a well-marked distinction between the upper members of the group with *Orbitoides papyracea* and the lower with *Nummulites garansensis*; and in one locality the upper member overlaps the lower, and rests on Khirthar limestone.

To the east of the Laki range the Nari beds are wanting, and the Manchhar series rests unconformably on the Khirthar, with some pebble-beds of the Gáj series intervening. But to the west of the range the Nari and the Gáj series are found in their normal sequence; and towards the coast the exact distinction which can be drawn elsewhere, stratigraphically and petrologically, between the Tertiary series is not possible: this is mainly due to the disappearance of the limestone element of the Khirthar and Nari series, and to the prevalence of sandstones and shales. The fossils, however, distinguish the groups; but the horizons of the zones of Nummulites and Orbitoides vary, being higher or lower in their proper series according to locality.

The upper sandstones of the Nari group have not yielded marine fossils, and in Upper Sind they contain the remains of plants.

The Nummulites become fewer in their species at the base of the Nari group, and cease to be found in the lower beds of the succeeding series, the Gáj.

The Gáj group, with a base of highly fossiliferous limestones and calcareous beds, more or less shaly and stratified, overlies the softer shales and sandstones of the Nari series. The development of the calcareous series is great; but it is subordinate to an arenaceous element. The sandstones are intercalated with clays with gypsum;

and shales and bands of limestone, highly coralliferous, are very constant.

The Gáj series rests conformably on the Nari series; although there is a mineralogical break, the passage is so gradual that calcareous bands of the Gáj series are found interstratified with the uppermost Nari sandstone. The Gáj series overlaps the Nari to the south and rests on the Khirthars, and is wanting in Lower Sind to the eastward of the Laki range.

North-east of Karáchi the series is highly developed, and massive limestones occur; they reach as far as the coast.

The uppermost beds of the Gáj series are variegated clays and grey sandstones, which form a passage into the everlying Manchhar strata, and contain species of *Ostrea*, *Corbula*, *Arca*, *Scalaria*, *Buccinum*, and *Turritella*. A crab of the genus *Typilobus* and the *Vicarya Verneuilii* already noticed have also been found there. The oyster is like *Ostrea multicostata*. The Echinoderms are of the genera *Maretia*, *Meoma*, *Breynia*, *Clypeaster*, &c. The Corals found, principally associated with the limestone-beds, are very different in their aspect from those of the underlying Nari group. They belong for the most part to reef-building genera, and some are represented in modern reefs by allied species, which grow in the surf and in the most exposed parts. The rest were dwellers in quiet water. Great masses of the coral limestone consist of *Stephanocœnia maxima* in casts, and the presence of the genera *Madrepora*, *Haliastræa*, and *Porites* is very significant of shallow-water conditions.

Resting on the Gáj strata is the Manchhar group; and where the Gáj beds are wanting, and even where the Nari series is deficient, this upper group rests on the Khirthars.

Of great thickness (10,000 feet on the flanks of the Khirthar range) the Manchhar series is divisible into an upper and a lower group. In the lower group much grey sandstone, soft and fine-grained, and composed of quartz with some felspar and hornblende, is found; and red sandstones and conglomeratic beds exist towards the base, as well as red, brown, and grey clays. The conglomerates do not contain pebbles of older Tertiary rocks; but cream-coloured clay, soft sandstone, quartzite, and micaceous shale are found in them. The conglomerates near the base are ossiferous; and the vertebrate remains are teeth or bones more or less rolled. There is no satisfactory distinction to be made on the Gáj river between the estuarine beds at the top of the Gáj series and the lowest beds of the Manchhar; and osseous remains have been found in the upper Gáj series.

The upper part of the Manchhars has a conglomerate in it with stones derived from the older tertiaries; below it are red, brown, or buff sandstones, with some clays; and there are no fossils.

Although usually conformable to the Gáj series, in places the Manchhars rest on the older rocks; and there are proofs of the Gáj strata having been greatly denuded before the deposition of the Manchhars.

In the Laki range the Manchhars have an ossiferous conglomerate near the base. In the Vero plain, running southward along the eastern side of the Laki range, south of Ranikot, large fragments of silicified wood are common, and some trunks of trees are upwards of 30 feet in length and 10 in girth. In the south, near Karáchi, the Manchhars pass into Gáj strata, and marine fossils are associated with the lowest beds.

The general conformity of this great tertiary series is evident—although local unconformities occur, and there is evidence in favour of there having been some disturbance of the older rocks before the deposition of the Lower Manchhar group. The subsidence which took place during the deposition of these thick shallow-water deposits was vast; and there were occasional slight upheavals. The final epoch of the mountain-formation occurred after the deposition of the Manchhars. The strike of the chains is in the main north and south; and the thrust came from the west to the east, and from east to west.

The date of the grand mountain-formation is subsequent to the deposition of the sedimentary strata forming the Upper Manchhars.

III. *General Results of the Study of the Corals of the Series.*

The Corals of the strata with *Cardita Beaumonti* below the trap are shallow-water forms; and their development indicates conditions unfavourable to vigorous coral-growth. There was no reef. The species are new; and there are no characteristic Cretaceous or Eocene forms present. The *Smilotrochi* and the *Rhabdophylliæ* are Secondary genera; but the first-named had species in the European Tertiaries, and may be represented in the shallow seas of the present day. The *Caryophylliæ* of the deposit have four cycles of septa only; and this gives them somewhat an ancient look; and the *Litharæa* would pass either as a Cretaceous or as an Eocene form.

The fauna as a whole is deficient in characteristic forms, and may be considered transitional.

It has been stated by the Geological Surveyors that the trap resembles the Deccan and Malwa trap; and the position of that vast outburst is anterior to the Nummulitic age, and subsequent to some Cretaceous strata in Western Central India. Certainly there are no Nummulites in the sands and shales which contain the fossils; and these are the remains of a Cretaceous crustacean.

The Corals of the Ranikot group are numerous in genera and species; and the fauna is remarkable for the number of simple forms it contains, and for the predominance of the family Fungidæ.

The compound Corals of the family Astræidæ, which so largely enter and have entered into the composition of reefs, are but feebly represented; and the few species which have been described did not aggregate to form massive limestones, but were seated on small flat circular epithecate bases. Fine as were many of the growths, yet it was a stunted Coral-fauna; and the shape of the majority of the forms would rather indicate that they lived in still water, and not in the rush of the waves. Certainly the Corals were beyond the rolling or scouring action of the sea; for any such movement would have displaced most of them.

As a generic assemblage, the Ranikot Corals are Eocene in facies; and of the twenty-seven genera three are new, and one is known in the Miocene of the West Indies. Out of fifty species seven are identical with European Eocene types, which are not found, however, as a whole, on one geological horizon in Europe. Some of them are found in the Lower Eocene; and the others are to be noticed in the deposits of San Giovanni Ilarione and of the Oberburg, in Styria, and in the higher horizon of Castel Gomberto. These forms are located in one series in Sind, and at the bottom of the Nummulitic group. Five species are closely allied to European forms out of the same great vertical series; and about seven others have a distinctly European facies. These 19 species give the Eocene character to the fauna.

The most distinctive genera are *Stylocœnia*, *Plocophyllia*, *Stephanophyllia*, *Stephanocœnia*, *Pironastræa*, *Reussastræa*, *Cyclolites*, and *Litharæa*. It is remarkable that five well-marked species of the genus *Turbinoseris* (nobis) should have lived on the Indian area; they are allied to those of the Eocene of St. Bartholomew in the West Indies.* The genus is Lower Cretaceous in England; and, under another name, it has lately been introduced into the Nattheim oolitic Coral-fauna.

The presence of a species of *Stylina* and of *Thamnastræa* recalls the Jurassic and Cretaceous ages: the first is found also in the next or Khirthar series of deposits; and the last probably lived longer in the southern seas. Only one genus, *Placocyathus*, is a Miocene type; and its distribution is West-Indian.

There is one very remarkable species, *Stylocœnia maxima*, nobis, in the Ranikot group; and it is so called from the great size of the intercalicular projections, which are little monticules in the British *Stylocœnia emarciata*, Lamk. sp. The breadth of the circular base of the coral is $3\frac{1}{4}$ inches; and it is $1\frac{8}{10}$ inch in height centrally. A concentric epitheca is on the base; and the upper surface is a mass of calices, and tall columns between them, some reaching $\frac{4}{10}$ inch in height. The minute columns in the British species are proved by the examination of these gigantic growths to be stunted or aborted calices. Some of the processes of *Stylocœnia maxima* have a perfect calice on the top, and the costæ come down the side; others have ill-developed calices, and a mere representation of a columella and septa. It is a common form, and is characteristic of the Ranikot series; its nearest ally is *Stylocœnia macrostyla*, Reuss, which is associated with *Nummulites planulatus* and *Cerithium giganteum* in the district of San Giovanni Ilarione.

Young specimens, of course, greatly resemble the European *Stylocœnia emarciata* of Bracklesham age.

Two other species of *Stylocœnia* are very common: one, *S. Vicaryi*, was described by D'Archiac and Haime; and the other is new. It has a large circular epithecate base; and the calices are large.

Astrocœnia, that very widely distributed genus, whose range, ver-

* P. M. Duncan, Quart. Journ. Geol. Soc. vol. xxix. p. 554.

tical and horizontal, is enormous, has several species in the Ranikot group: and *Astrocœnia ramosa*, Sowerby, a Cretaceous type from the Turonian of Gosau, found also in the Eocene of St. Bartholomew in the West Indies, is present in Sind, and has the usual tuberose branchlets so characteristic of the form.

Large solitary Corals of the genus *Montlivaltia* abound, and also a characteristic series of simple forms which I have had the opportunity of naming after Mr. Fedden, to whom the geology of Sind owes so much. The genus *Feddenia* had its young forms growing on small shells, which, with the growth of the base of the Coral, were enclosed, and the Coral became free. This is not an unusual habit in some two or three species of Corals of another family, now living; and an elongate base is produced. One of the results of this change of condition was that the costæ did not radiate upwards from the peduncle, as is seen in the larger forms, but from the whole length of the enclosing base. Another peculiarity is that the epitheca is like a broken mosaic.

There are three well-marked species of this genus; and one has two good varieties in the Ranikot series. It is near *Montlivaltia* as a genus; and, admitting the great variability of all simple or solitary Corals, it is very possible that the unusual method of early growth may have produced correlative changes in the general shape and septal arrangement. The genus was restricted to this Lower Eocene horizon. Amongst the great series of Fungidæ found in the Ranikot group there are two European forms of *Cyclolites*; and the other seven species of the genus are well differentiated.

Finally, the genus *Stephanophyllia*, amongst the Eupsammineæ, ought to be represented, to give the full early Tertiary facies to the Cyclolitic assemblage. *Stephanophylla indica*, from Jhirk, in the Ranikot group, maintains the character of the genus for beauty, and is an exquisite gem. Its affinities are rather with the Cretaceous species; and it differs but slightly from *S. Bowerbanki* of the Lower Chalk in its main characters, and from *S. discoides* of the London Clay more decidedly. Like most of the Ranikot corals, the individuals of the new species began life by settling down on a Nummulite; this formed the permanent base of the coral; and the usual radiating costal arrangement of *Stephanophyllia* either does not exist or cannot be seen for the Nummulite.

Khirthar Series.—Sixteen species of Corals were found in this series; but ten of them were taken from beds so high up that it is not satisfactorily proved whether they are at the top of the Khirthars, or form the base of the Nari group, next in vertical succession. By separating these ten species, an indubitable Lower-Khirthar fauna is decided to have existed: its biological conditions were unfavourable to vigorous coral-growth; and there were no littoral or reef-building forms. From the analogy of recent forms, which are identical generically with those of the Khirthar series, or whose shape resembles that of the ancient species, a sea-floor at the depth of from 20 to 200 fathoms or more would be indicated.

The species belong to the genera *Trochocyathus*, *Leptocyathus*, *Stylophora*, *Montlivaltia*, *Calamophyllia*, and *Astrocœnia*. The *Trochocyathus* is one of the discoid group, and the *Leptocyathus* is of course a low flat Coral. The *Stylophora* is a minute Coral; and so is the *Astrocœnia*. But the *Montlivaltia* is a finely grown form; and so is the *Calamophyllia*. Of these, *Stylophora contorta*, Leymerie, has also been found in the Eocene of the West Indies and at La Palarea in Europe; and *Astrocœnia numisma*, Defrance, sp., is a Nummulitic form at Gap, in the district of Nice. This little assemblage is thus clearly of Eocene age. No distinction can be made between this and the preceding deposit, as regards age, from the Corals.

Now the ten species, the horizon of which may be of Upper Khirthar or Lower Nari age, belong to genera whose morphology indicates the presence of totally different physical conditions from those which environed the stunted, simple, and the few large Corals of the lower horizon. They were shallow-water and reef-building forms; and the genera are *Stylina*, *Latimœandra*, *Hydnophora*, *Favia*, *Isastrœa*, *Pterastrœa*, *Plesiastrœa*, and *Porites*. There is not a simple Coral amongst them; and the facies is singularly mixed, old and new, Mesozoic and Cainozoic genera existing together.

The species *Hydnophora maliriensis*, nobis, is allied to *H. venusta*, Catullo, of the European Nummulitic. *Porites Pellegrinii*, D'Achiardi, is found in Europe at San Giovanni Ilarione; and *Porites indicus*, nobis, is allied to a species from Crosara, Oberburg. The distinctness of this fauna from that of the Ranikot group is evident enough; but it is still Nummulitic in facies and character.

The Nari Series.—From the remarks already made upon the localities of some of the presumed Khirthar Corals, it is as well to admit that some upheaval took place at the close of that period, and produced fringing-reef-building or bank conditions. But they did not prevail throughout the accumulation of the whole of the Nari series; and it is somewhat remarkable that no species passes up from the reef-building horizon into that of the Nari proper.

The genera of the Nari group above the base, indicate rather vigorous coral-growth, and both deep- and shallow-water conditions. The genera *Trochocyathus*, *Trochosmilia*, *Montlivaltia*, *Cycloseris*, and *Cyclolites* are the simple forms; and the vigorous compound forms are included in the genera *Dasyphyllia*, *Rhabdophyllia*, *Leptoria*, *Mœandrina*, and *Prionastrœa*.

The *Trochocyathi* of the Nari series are remarkable for having commenced their growth in a discoid shape. Some retained that shape; but one in particular, *Trochocyathus nariensis*, nobis, grew upwards from its disk-shaped base in a perfect cylinder, reaching 2 inches in height.

Trochocyathus cyclolitoides, Ed. & H., is a widely distributed European Eocene coral, and is found in the Nari series of Sind.

Stylophora pulcherrima, D'Achiardi, from the Eocene of Friuli, *Trochosmilia varicosa*, Reuss, from Crosara, *Stylocœnia taurinensis*, Ed. & H., from European Eocene and Miocene strata, and *Cycloseris*

Perezi, Ed. & H., from the Nummulitic of Nice, are also amongst the Nari corals. Hence, out of the twenty species of fossil Corals in the Nari series, one is found at a higher horizon, and one fourth of the number are found in the Upper Nummulitic and Oligocene deposits of Europe.

Taking the Ranikot, Khirthar, and Nari Coral-faunas as a whole, there are 76 species of Corals in them and several varieties; and of these 16 are identical with European forms which are found in strata yielding Nummulites to the top of the Oligocene. There are also eight species in the Sind series, closely allied to those of the European fauna; and whilst some species are common to the West-Indian Eocene, an important genus is also common to both localities. The absence of species passing up from one series to another is very remarkable.

The Gáj Series.—This series of strata contains a large number of Corals in bands; but although most of the forms are massive and compound, and suited for reef-building, the majority are pedunculate instead of covering a large surface and incrusting. Some are very massive; and the presence of species of *Madrepora*, an essentially reef-building genus, with *Porites*, *Agaricia*, *Echinopora*, *Prionastrœa* *Plesiastrœa*, *Brachyphyllia*, *Leptoria*, and *Dasyphyllia* would indicate, at the present time, very active shallow-water coral-growth. The majority of the Gáj genera still flourish; and most of those which are extinct had the structures requisite for reef-building. The Astræidæ as a family preponderate, and simple Corals are rare, in the collection. But although the facies of the Gáj coral-fauna is very recent, and there are very few extinct genera, still the modern Coral-fauna of the Eastern and Red Seas is not represented by a single species. Two species are identical with Miocene West-Indian forms; and one is found in the Nari series.

It is interesting to find the West-Indian Miocene and recent genus *Antillia* represented. Nevertheless the evidence afforded by the Corals is in favour of a mid-tertiary age being given to the 41 species from Gáj.

In the communication to the 'Annals and Magazine of Natural History' (1864, vol. xiii.) I described several species of fossil Corals from unknown geological horizons in Sind; and it is not difficult, with the lists of the genera and species which have been collected by the Geological Survey of India, to decide whence the majority came. Thus *Oculina halensis*, nobis, *Antillia dentata*, nobis, *Antillia ponderosa,* Ed. & H., *Cladocora haimei*, nobis, *Hydnophora rudis*, *H. plana*, *H. hemisphœrica*, nobis, point, with *Cyathoseris valmondoisiaca*, Ed. & H., and *Agaricia agaricites*, Ed. & H., to a late Miocene horizon. They were picked up in the neighbourhood of Karáchi, and doubtless came from the highest beds of the Gáj series.

Finally, many specimens of Isidinæ have been found in the Gáj series; and some of them closely resemble modern forms. No Nummulites occur in the Gáj series; and the Zoantharian evidence indicates a Miocene age, and not an early one.

The Sindian formations, including the transitional beds with *Cardita Beaumonti* beneath the trap, and the Gáj series at the top, contain 136 species of Corals and many varieties. Of these, 9 belong to the transitional series, and 56 to strata in which Nummulites exist in profusion. The Nari series, with few species of Nummulites and with *N. garansensis*, a European type characteristic of the Upper Nummulitic or Oligocene, contains 20 species. The Miocene strata of Gáj contain 41 species. I omit from these numbers all species from doubtful localities. Thus, as only one species transgresses, there are five Coral-faunas; and if the separation I have proposed at the base of the Nari series is right, there are six in the same area, included in a prodigious depth of sedimentary strata. The study of the Corals does not indicate that there was ever a sea there with a depth of many hundred fathoms; on the contrary, shallow-water conditions (within 20 fathoms) usually prevailed during the slow oscillation of the area, in which subsidence on the whole predominated.

IV. *The Equivalence of the Manchhar Strata of Sind and the Sivâlik Group of the Himalayas.*

The Geological Survey of Sind by Blanford and Fedden has proved that in some places the Manchhar strata succeed transgressively to the Gáj series, whilst in others there has been erosion of the marine deposit before the deposition of the freshwater one, or else the lower group is absent. Bones of *Rhinoceros sivalensis* have been found in the uppermost Gáj strata. There is no doubt that the greater part of the coralliferous strata of the Gáj series accumulated in shallow water, and yet beyond the reach of the wash-down of a coast-line. But the lower Manchhars were deposited in shallow water within the scope of terrestrial denudation. There must have been considerable general changes in the physical conditions of the area: and they persisted; for coral life has never since prevailed there. The first change probably was one of slight general upheaval; and subsequently a slow and progressive subsidence occurred, during which the vast vertical development (8000 to 10,000 feet at least) of the lower and upper Manchhars accumulated.

Conglomerates, coloured sandstones (grey, green, and red in tint), and clays, are the prevailing deposits on the inner flanks of the vast mountain-system which surrounds Peninsular India, from Sind to Burma inclusive. Made up of stone brought down by the rivers of the extra-peninsular mountain-system, before it became of very great height, and when its breadth was probably much greater than it is now, these deposits are to be traced to the north of Sind in the Suleiman Mountains, in the Salt range, covering much of the surface of the Northern Punjab, and then, forming part of the sub-Himalayan range, as far east as the Brahmapootra. Similar deposits are found, in diminished thickness, in the Assam range; and they became important in the Burmese territories. The Sindian succession of the strata is the normal one; and it extended to a certain distance northwards; moreover it is exemplified in the Burmese area. But in the great central area of the Himalayas proper there was no marine Miocene. No marine beds, the equivalents of the Gáj series of Sind and Burma, underlie the Sivălik deposits in the Sub-Himalayas.

There was open sea during the Nummulitic age where the great semicircle of extra-peninsular mountains now exists; and marine conditions persisted on the west and east during the Miocene period; but a post-Nummulitic upheaval developed a land-surface and hill-tracts from Kashmir to Assam.

This upheaval commenced before, but culminated after, the close of the Eocene age; and a considerable thickness of purple sandstones, red clays, and grey and purple sandstones containing plants accumulated in the swamps on the plains of that age, near the mountains on the edge of the Nummulitic sea-floor.

These plant-bearing strata and the underlying Nummulite-bearing strata have a minimum thickness of 2000 feet, and they form the Sirmúr series of Indian geologists.

This series underlies unconformably the vast freshwater sedimentary formation comprising the Náhun and Sivălik strata, which attain a thickness of about 15,000 feet, and, except where buried beneath recent deposits in one locality, extend, with a varying development, along the south of the great mountain mass, and are found on one of the great tablelands to the north of the Central Himalayan axis. The lower, or Náhun unfossiliferous, series consists mainly of grey lignitiferous sandstones. On it the upper, or fossiliferous Siváliks, accumulated as sandstones and clays; and on the top of all are conglomerates. A great fauna is represented in all parts of the Sivălik deposits above the Náhun beds.

From the lie of these sedimentary strata, it may be very reasonably inferred that the Náhun and Sivălik deposits are the equivalents of the Lower and Upper Manchhars of Sind; and the inference may be extended to the Upper Tertiaries of Burma. There is an outlier of this series and of its lower member in the Gulf of Cambay or Perim Island.

In attempting to establish exact parallelism between the Sindian and the Himalayan deposits called Manchhar and Sivălik, it must be noticed that the vertical development of the last-named rocks is the greatest, and that whilst the lowest beds of the Sindian series are fossiliferous, those of the Náhun beds of the Siváliks are not*. On the other hand, osseous remains are found throughout the Siváliks proper (above the Náhun beds), but not in the Upper Manchhars in a recognizable form.

The Manchhar and Sivălik series have been upheaved, uptilted, and in the last instance greatly contorted. Both series were the youngest implicated in the great orographical development; and although they are on different lines of strike, they were affected during the same geological period.

The denudation of their exposed edges has been great. Both are

* Possibly the ossiferous deposit at Kushálghar, near Attock, is of Náhun age. See further on.

covered in some places with high-level gravels; and the Siváliks of the great tableland of Hundes underlie deposits referable to the glacial period, whose effects were not felt so far south as Sind.

In considering the palæontology of these deposit it may be stated that the osseous remains are found on several horizons.

First, the Rhinoceros-remains which were found included in the Marine Miocene series of Gáj in Sind, lead to the inference of the existence of neighbouring contemporaneous land-surfaces and shallow seas—that is to say, of Miocene land washed by a Miocene sea. The Rhinoceros, according to Mr. W. T. Blanford, F.R.S., is *Rhinoceros sivalensis*.

Secondly, the fragmentary bones and teeth found in the conglomerate near the base of the Lower Manchhar formation in Sind accumulated later on than the Gáj series.

The following is the list of the vertebrate remains which were collected by Mr. Fedden, and named by him and Mr. Lydekker in the publications of the Geological Survey of India:—

Amphicyon palæindicus.
Dinotherium pentapotamiæ.
—— indicum.
——, sp. nov.
Mastodon perimensis.
—— latidens.
—— Falconeri.
Rhinoceros palæindicus.
——, sp. near R. deccanensis.
Acerotherium perimense.
Sus hysudricus.
Hemimeryx, sp.
Sivameryx, 2 sp.
Chalicotherium sivalense.
Anthracotherium silistrense.
Hyopotomus palæindicus.
Hyotherium sindiense.
Dorcatherium majus.
—— minus.

EDENTATA.

Manis sindiensis.

REPTILIA.

Crocodilus, sp.
Chelonia, sp.
Ophidia, sp.

The conglomerate containing the bones was composed of the wash-down of the Lower Manchhars themselves.

Thirdly, the fossil bones which have been discovered in considerable quantities in a conglomerate on Perim Island (although their place in the geological series cannot be determined, from the absence of a succession of rocks) appear to have belonged to a fauna allied to that of the Manchhars and to that about to be noticed.

The species which have been determined by Falconer and Lydekker are:—

Dinotherium indicum.
Mastodon latidens.
—— perimensis.
—— sivalensis.
Rhinoceros, sp.
Acerotherium perimense.
Brahmatherium perimense.
Camelopardalis sivalensis.
Capra perimensis.
Antilope, sp.
Sus hysudricus.

The remains are included in sandstone blocks.

The same, or a slightly higher, horizon is recognized far away to the north, not, however, by its geological position, but by the fossil remains, in the neighbourhood of Kushálghar, forty miles south of Attock, in the Punjab. The deposit contained, according to Falconer and Lydekker, the following genera and species:—*Dinotherium* *pentapotamiæ*, *Mastodon*, *Listriodon pentapotamiæ*, *Rhinoceros*, *Merycopotamus*, *Dorcatherium*, *Sanitherium Schlagintweitii*, and *Amphicyon palæindicus*.

It is remarkable that all these horizons should contain *Dinotherium*.

Fourthly, the Sivâlik clays, sands, and conglomerates above the Náhun series present an assemblage of genera and species second to none in importance, and much grander generally than the existing fauna, which is very slightly represented. A number of genera which had lived in the Miocene elsewhere were associated with genera not known in mid-Tertiary deposits, and which have lasted either into Post-Pliocene or into Recent times. The *Dinotheria* are absent. Omitting the common Miocene genera and stating the others, an African element is noticed, as in the instance of Pikermi in Greece. The characteristic genera are *Palæopithecus*, *Macacus*, *Semnopithecus*, *Stegodon*, *Elephas*, *Loxodon*, *Hippopotamus*, *Camelopardalis*, *Camelus*, *Bos*, *Bubalus*, *Bison*, *Cervus*, *Equus*, *Canis*, *Ursus*, *Mellivora*, *Meles*, *Lutra*, *Enhydriodon*, *Tapirus*, *Hystrix*, *Mus*, *Rhizomys*, *Crocodilus*, *Gavialis*, *Varanus*, *Ballia*, and *Emys*.

Moreover many of the freshwater Mollusca are identical with recent forms.

It appears that these wide horizons are separable into an older series, with *Dinotherium*, *Hyotherium*, *Hemimeryx*, *Sivameryx*, *Hyopotamus*, *Anthracotherium*, *Acerotherium*, and *Manis*, but without *Elephas* and the later bovines; and into a younger series, in which genera of an African type, such as *Hippopotamus* and *Camelopardalis*, are found, and without the older types.

The first series is in relation with the Lower Manchhars, and the second with the Sivâlik deposits above the Náhun beds. But the interesting fauna from Kushálghar appears to be probably of Náhun age; and if that should be proved eventually, the succession of two fairly distinct faunas, linked together by some species, will be evident.

Finally, the Post-Pliocene deposits of the Jumna area, and also of the Nerbudda and other peninsular rivers, contain some species of the Sivâlik horizon.

V. *General Considerations regarding the Age of the last Himalayan Upheaval.*

It might be supposed, considering the ready manner in which European mammalian faunas are placed in the scale of geological succession, that the contemporaneity of some of them with the Sivâlik-Manchhar assemblage of vertebrates would be easily determined, and a geological age given for the latter without doubt.

But the critical examination of the positions in which many of the European mammaliferous deposits have been found, indicates that the manner in which the Tertiary deposits have been classified by means of the fossil Mammalia is open to exception.

Two well-known examples of European mammaliferous deposits which resemble, in their succession, the Sivâlik-Manchhar series are those of Eppelsheim and Heppenheim and of Pikermi. At Eppelsheim sands in small patches are at the top; and they contain a few specimens of fossil Rodentia, Insectivora, and Carnivora. A conglomerate is beneath, and contains the Dinotherian remains, and also those of Rhinoceros and Mastodon; and all are remanié. At the base of the series there is a clay with freshwater shells; and it rests conformably on a marine limestone; and this is of late Miocene age.

At Pikermi the deposit, the bones from which have been so ably described by Gaudry and commented on by W. T. Blanford, rests on a freshwater stratum of Pliocene age, and a Miocene lacustrine series underlies the whole unconformably.

Now at Sind as at Eppelsheim the underlying marine beds are Upper Miocene in age, and freshwater conditions prevailed subsequently, during which the osseous remains were depoisted.

What is the age given to the *Dinotherium*-conglomerate at Eppelsheim? Carl Vogt, influenced apparently by the presence of *Dinotherium*, and regardless of any stratigraphical arguments, and not considering the important changes which had occurred in the area, in the relative level of the land and sea-floor, decided that the overlying freshwater beds are of mid-Tertiary age. But Credner, dealing with the subject more philosophically, and not being so much impressed with the presence of a genus which elsewhere is represented in Pliocene strata as by the evidence of the considerable mutations which had occurred in the physical geography of the district, and which had brought a marine deposit above the original sea-level, places the bone-bearing conglomerates in the Pliocene age. Thus one geologist associates the land and marine elements together, and the other separates them.

The comparison which can be instituted between the Manchhar and Siválik deposits and those at Pikermi is very close; and, according to the ordinary rules of stratigraphy, if the osseous remains at the last-mentioned locality overlie Pliocene deposits, the animals which left their bones could not have been of Miocene age. Yet Prof. W. Boyd Dawkins, in his contributions to this Society, asserts that the Pikermi fauna flourished in the Miocene. Evidently there is a great diversity of opinion regarding the age which should be given to land-surface remains overlying marine strata, freshwater and estuarine deposits intervening. And if this subject is studied it will be found that great discrepancies of opinion have existed in regard to similarly placed deposits in many of the great formations.

About the relative age of some superincumbent terrestrial remains there is no discrepancy of opinion. The Coal-measures are associated with the underlying grits and limestones; and the land remains of the Inferior Oolite are similarly connected in classification with the marine deposits beneath them. When the lateral extension of the strata can be traced, and distant marine equivalents of the overlying series can be proved to contain fossils representative of or identical with those of the underlying series, the land-surface is classified with the formation in which the marine strata are placed. Or when there is a succession, on the same area, of marine beds over the terrestrial and freshwater series, if the fossils of the upper strata resemble those of the deeply seated marine ones, the whole belongs to one great aspect of nature.

It will be found that there can be no exception made to placing the Woolwich and Reading series out of the formation which includes the white chalk; but the propriety on any grounds of linking the Purbecks on to the marine Portland is open to exception.

Except in instances similar to those of the Carboniferous and Inferior Oolite, and where there is also decided unconformity, the question can only be answered after a careful consideration of the amount and extent of area implicated in the changes in the physical geography which may fairly be assumed to have occurred since the underlying marine deposit was completed. The upheaval of *limited* marine deposits recognizable as belonging to a particular formation, and the accumulation upon them of freshwater deposits and conglomerates, would hardly necessitate the belief in such a change in the aspect of nature as would warrant their classification under two great geological ages. But when the same phenomenon is witnessed over *widely* separated areas, and a conglomerate is followed by some thousands of feet of fluviatile and other freshwater strata (the wreckage of high land close at hand), it becomes certain that the physical change has been wide enough to admit of an alteration in the geological nomenclature.

With regard to Sind, the Lower Manchhars usually rest conformably on the Gáj marine Miocene, and marine, estuarine, and freshwater intercalations exist at their base and before the conglomerate is fully developed. In one locality the Manchhars rest on a greatly denuded surface of Gáj strata.

Upheaval (slow, irregular, and on a very grand scale) occurred subsequently to the deposition of the Gáj series; and a marine tract became estuarine, fluviatile, and a region of wearing of high land. Subsequently the enormous subsidence took place, doubtless almost synchronously with the deposit of the thousands of feet of the Manchhars; and yet the sea never broke in: it was far away.

The area of change was vast; and it appears to be unreasonable to associate all these deposits under one geological formation.

The disassociation of the Manchhar and Gáj series is a necessity; and the nature of the fauna, so singularly allied to that of Pikermi, necessitates its relegation to the early Pliocene time.

In following up this subject it must be remembered that the Siválik strata, the horizon of which is above the Lower Manchhars, have a vast vertical as well as horizontal development, and that osseous remains have been found in them throughout their height. The fauna as a whole has a later facies than that of the Lower Manchhars, and resembles, even in its African element, that of Pikermi.

On the ground of inferred equivalency with the Upper Manchhars, and of faunal alliance with the assemblage at Pikermi, it must be credited that the Siválik strata are of Pliocene age.

There is another argument which has not hitherto been employed and which favours this theory.

The Sivâlik strata rest on, or are in contact with (along a line of fault), certain plant-bearing strata of the Sirmúr series which are associated with the underlying Nummulite-bearing Eocene rocks of Subáthu.

The nature of the flora, so far as it has been examined, is not very foreign to that of India at the present time; and by the same kind of reasoning which asserts the separation of other terrestrial and underlying marine strata, these beds, called Kasaoli and Dugr'hai, may well be the remains of the Miocene land.

Whence were the vast thicknesses of the sands, clays, and conglomerates of the Manchhar-Siváliks derived? They represent a ruined mountain-chain in bulk; and they are found not only on the flanks of, but also within, the orographical systems of which they form parts.

It appears from the study of the history of the Himalayas by Strachey, Stoliczka, Medlicott, and those Indian Geological Surveyors who have laboured so industriously of late years, that a low mountain-chain existed on the area after the Nummulitic age—the results of a post-Nummulitic earth-movement. It was probably a broad chain, and not a sufficient barrier to prevent the roaming of the animals on and over it in the subsequent geological age. This chain appears to have had an axis of old rocks; and the whole suffered denudation during the age of the Sivâlik Mammalia. In Hundes Strachey found the great tableland (now at an altitude of from 14,000 to 16,000 feet) to consist of sediments filling up a basin in old rocks to the depth of 3000 feet—sediments which included osseous remains of animals that could not have traversed high and difficult mountain-ground.

Part of the Sivâlik sediments were formed out of low mountain-ground by fluviatile denudation; but to account for the vast development of the rest on the flanks of the present mountain-system, it is necessary to admit that the upheaval, and much of the north-and-south crush of the Himalayas, occurred *pari passu* with the slow accumulation. Elevation and diminution of the breadth of the area progressed; and doubtless much of the great crush which folded and often reversed the flanking strata was final.

The Sivâlik strata rest on the flanks of the chain and on old rocks within the range; and they were the youngest deposits affected by the mountain-making. Hence the Himalayas, as a grand system, culminated during and subsequently to the collection of these strata, which have been pronounced to be Pliocene in age.

The Sivâlik deposits in the tableland of Hundes are overlain by relics of the great glacialization of the Himalayas. Hence, before the vast glaciers of the glacial period accumulated, valleys had been worn out and denudation had proceeded. So it is necessary to recognize that the culmination of the movements which developed the height of the Himalayas occurred in preglacial times and during the Pliocene age.

To complete the serial changes, it is to be remembered that a Postglacial fauna was found in the old alluvium of the Jumna, a wash-down of the Himalayas.

With regard to the Upper Manchhars, they were implicated in the great orographical movement, which was contemporaneous throughout the extrapeninsular area of India; and they are of Pliocene age.

The details regarding the succession of strata and of many of their organic remains are to be found in the publications of the Geological Survey of India, and in the communications to this Society by Strachey, Grant, Falconer, and others. The 'Manual of Indian Geology,' by Medlicott and Blanford, an abstract of the labours of the Survey, contains them in a condensed form. I am under great obligations to all those writers, and also to Messrs. Medlicott and Blanford for much unpublished information; and in thus heartily acknowledging my obligations, I am glad to have the opportunity of expressing my assent to their conclusions regarding the age of the Himalayas.

Discussion.

The President remarked on the persistence of Mesozoic types in the Tertiary strata of the Himalayas.

Mr. Blanford expressed the obligations of himself and other Indian geologists to Dr. Duncan for his researches on the Corals which they had collected. The base of the series of Sind consists of a limestone containing Hippurites; and above these Cretaceous beds are strata partly unfossiliferous and the representatives of the Deccan traps, the whole being overlain by the Lower Eocene and Nummulitic. This succession is shown both in the Laki and the Khirthar ranges. The Nari or Oligocene group is 5000 or 6000 feet thick; its upper subdivision, which is much thicker than the lower, is of freshwater origin, and contains imperfect plant-remains. This is overlain by the Gáj and Manchhar. The unconformities which occur in the series are purely local. He was gratified to find that Dr. Duncan had arrived at the same conclusion as the Geological Survey of India as to the age of the Siválik beds. He replied to the opinions expressed by Prof. Boyd-Dawkins and Mr. Bose on this subject.

Lieut.-Col. Godwin-Austen remarked upon the greater contortion of the Nummulitic strata in the Western Himalayas as compared with those of Assam.

The Author stated, in reply to the President's remarks, that while the *genera* of Corals are remarkably persistent, the *species* are not. He bore testimony to the great value of the volume published by the Geological Survey of India. He doubted the value of the terrestrial Mammalia as fixing the age of the strata overlying the Eocenes.

15. *The* Archæan Geology *of* Anglesey. By C. Callaway, Esq., M.A., D.Sc., F.G.S. *With an* Appendix *on the* Microscopic Structure *of some* Anglesey Rocks, by Prof. T. G Bonney, M.A., F.R.S., Sec.G.S. (Read January 5, 1881.)

[Plate VIII.]

Fig. 6. Section in lower Quarry, Nebo.

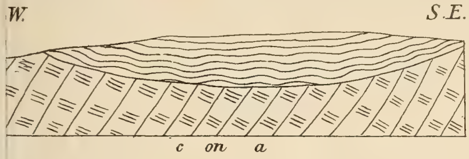


Fig. 5. Section in upper Quarry, Nebo.

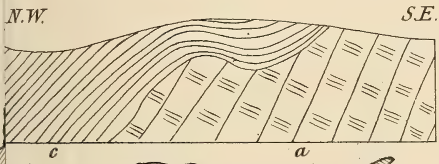


Fig. 3. Section across Mynydd Llwydiarth.

Fredk Dangerfield, Lith. London

Introduction.

I have to submit evidence in support of the conclusion that there are represented in Anglesey two Precambrian or Archæan groups, each distinguished by well-marked lithological characters. They may be named respectively the Slaty and Gneissic formations. The "Pebidian" schists, as recognized by Dr. Hicks, I include in the gneiss group; but, in other parts of the island, I have worked out a great assemblage of fragmental felspathic rocks, which I believe to be of true Pebidian age. I shall also attempt to prove that the quartz rocks of Anglesey are included in the gneissic series. The microscopic notes, kindly furnished by Prof. Bonney, are based upon the specimens only, and have all the value of independent evidence. The growing importance of these ancient rocks would seem to require that the provisional term "Precambrian" should give place to a word which can be permanently used: and I have ventured to adopt the term "Archæan," so widely employed by Continental and American geologists. To the words "Azoic" and "Eozoic" there are obvious objections.

A. Description of Areas and Sections.

I. Menai Anticline.

For convenience I accept this name for the rocks lying between Menai Straits and the great fault which throws down the newer Palæozoic rocks of Malldraeth Marsh, though the term is not strictly applicable. It is true that the strata on the south-east side of the area dip to the south-east, and those on the north-west side to the north-west; but between these two extremities the undulations are frequent, and some of the dips are probably overthrows.

a. *Gneissic Series.*

Two Varieties of Gneiss.—The structure of the area is rendered much clearer by the recognition of two prevailing gneissic types—a dark micaceous or hornblendic variety, associated with chloritic schists*, and a greyish or light-red rock clearly foliated into an ordinary ternary gneiss. In the Craig-yr-allor anticline † the two varieties are also recognizable, the grey gneiss passing up through the dark type into the granitoidite. In the Menai district the dark schist holds the same relation to the grey variety, and the passage between the two may be seen at many points.

1. *Gneiss south of Pentraeth.*—Next to the fine section at Gaerwen ‡, the rocks south and east of Pentraeth require notice. The band coloured "greenstone," running from Tai hirion north-north-east to Plâs-gwyn lodge, appears to be a highly-altered hornblendic gneiss, with a north-west dip. In the field to the south-east of the lodge is a small quarry of typical grey gneiss; and in the plantation

* Throughout the paper the terms "schist" and "schistose" are strictly confined to foliated rock.

† Geol. Mag., March 1880, p. 119. ‡ Geol. Mag., March 1880, p. 121.

a few yards to the north-west we find the dark-green schist in its usual position above, both dipping to the north-west.

Following the strike to the north-east, the gneiss is seen to contain angular pieces of quartz, some of which are flattened in the foliation-planes, so as to appear like ordinary folia.

2. *Mynydd Llwydiarth.*—This elevated ridge, trending to the north-east for nearly a mile and a half, is composed of highly contorted gneiss. The general dip is north-west; but in some places the beds undulate to the south-east; and the thickness cannot be great. The rock is more quartzose than usual; and the quartz fragments become much more numerous,—the two facts suggesting the proximity of quartz land. The gneiss, rolling in frequent contortions, is finely exposed in low vertical cliffs; and the angular pieces of white quartz studding and projecting from the surface produce a very striking effect. Both types of gneiss appear to be present; but the felspar being less abundant, the rock is brought into closer resemblance to the micaceous and chloritic schists of Holyhead. On the north-western slope the gneiss is extensively brecciated, and the presence of a fault is further inferred from an abrupt transition to younger formations. At the foot of the slope, near the fault, the gneiss becomes somewhat granitoid, suggesting the commencement of the passage into granitoidite, which is seen so clearly in the Craig-yr-allor anticline. At the extreme north-east of the ridge, on Red Wharf Bay, the green schist is exposed for some distance across the strike to the east; but south of Wern we come onto the grey gneiss, all the dips being north-west. Further to the east, at Bryn y Castell, the grey type is again seen, but with the dip reversed; and at Hafodty, still further to the south-east, the dark schist comes in again. This is a clear anticline, the grey gneiss exposed at the apex throwing off green schist in opposite directions. The structure of this district is shown in Pl. VIII. fig. 3.

3. *Gaerwen to Menai Bridge.*—Crossing the anticline from Gaerwen, we find at the railway-junction that the dark schist has rolled over to the south-east; but half a mile to the south-east, near Llanddaniel, the series, represented by contorted quartzose chloritic schist, dips north-west. Exposures then are rare till we come to the Anglesey column, where dips are in opposite directions, but usually to the north-west. This rock is of the ordinary dark green type, occurring everywhere above the grey gneiss in both the Menai and Craig-yr-allor areas. It has been described by Prof. Bonney *. On the Straits, near the west end of Menai Bridge, green schists occur of the ordinary varieties.

From the above facts it is clear that the rocks of the anticline belong to the gneiss series. Well-foliated gneiss occurs at numerous localities; and the green schist is so intimately associated with it, as an upper band, as to remove all shadow of doubt that the two types form one unbroken group. In this area I have not found a trace of any thing but true crystalline schists.

The thickness of the group is not great. The foldings are nume-

* Quart. Journ. Geol. Soc. vol. xxxv. p. 308.

rous, the lower gneiss being brought up to the surface at many points. Probably the entire series is exposed west of Gaerwen, where the total thickness can hardly reach 1000 feet.

An isolated mass of schist occurs south-west of Pentraeth. It is about a mile long by half a mile broad, and is bounded by faults on all sides. Carboniferous Limestone surrounds it on three sides. On the east it is separated from the main mass by a faulted strip of the formation now to be described.

b. *Slaty Series.*

This wedge is composed of rocks of a newer Archæan group. At Tan y graig, south-west of Pentraeth, is a greenish, coarse, slaty variety. In the fields to the north-west, a jaspery rock projects in small knolls through the turf; but its relation to the bedded type is obscure. Crossing a hollow to the east, we come to a ridge, the western slope of which is occupied by massive breccias. The fragments and the matrix are similar, and are composed of a grey and purplish dolomite (Note 40, p. 235). Further to the north-east, above Wugan bach, is a light-purple slaty rock, which in places is literally smashed. Between this point and Plâs gwyn, along the ridge, the prevailing type is a purplish ashy rock, sometimes brecciated, and in places altered almost to a hornstone. The dip is high to the north-west. The breccias of this ridge are obviously connected with faulting. North of Plâs gwyn, on the same strike, is a puzzling rock, which, under the microscope (Note 41, p. 236) appears to be a limestone rendered impure by volcanic mud. Slaty beds are again seen to the north-east of Pentraeth, dipping south-east.

For the greater part of its length this mass is separated from the Menai anticline by a faulted strip of Palæozoic shale; but north-east of Rhiwlas it comes up against the gneiss, the fault between the two formations running along a hollow. The heavy breccias which fringe both groups point to excessive fracture and crushing.

II. Llangefni "Syncline."

Crossing the Carboniferous strata of Malldraeth Marsh, we come to an altered and contorted group of rocks which bear a superficial resemblance, especially in their colour, to the Menai schists, and have hitherto been regarded as a part of the same group. But on a careful examination of the lithology of this series, fundamental differences are observable. Even my first day's work in the district convinced me of the existence of Pebidian rocks of the St.-David's type; and fuller working-out of the area brought to light analogies with other Pebidian localities.

Slaty rocks occupy only the south-eastern side of the apparent syncline lying between the Carboniferous on the south-east and the granitoid band on the north-west, the north-western side being composed of gneissic strata. The two groups are brought together by a fault or faults; but as they dip towards each other, an apparent basin is formed (see section near Aberffraw, Pl. VIII. fig. 2).

a. *Slaty Series.*

1. *Llangristiolus Grits and Slates.*—The lowest beds I have observed are exposed near the Llangristiolus turnpike. The rock is clearly bedded; but its lithology is obscure, and the jointing is so close that clean fractures are hard to get. It appears to be a quartzo-felspathic grit, altered into a sort of hälleflinta. Some bands are coarser, grains of quartz and felspar being visible to the naked eye. A similar rock is common in the Pre-Cambrian rocks of the Church-Stretton district (Shropshire).

A little further to the north, near Cerrig ddwyffordd, a quarry-section is very interesting. At the base is a purplish grey felspathic grit (Note 42, p. 235). This is overlain by a pale-green slaty rock of Charnwood type, associated with, and apparently passing into, a sort of porcellanite (Note 43, p. 234), singularly like a rock at Caer bwdy, St. David's. The Charnwood facies of these varieties is also noted by Prof. Bonney. The section is capped by a repetition of gritty bands. The dip is northerly, at from 40° to 50°. Similar rocks are exposed in neighbouring fields.

2. *Llangefni Conglomerates and Shales.*—To the west and north-west of the Llangristiolus sections are several exposures of a greenish conglomerate. It is seen on the Holyhead road, near Waen hir, and north of Cerrig ddwyffordd, at the arrow mark, but is very fully exposed in the railway-cuttings north-west of Llangefni, the enclosed fragments, weathering white, being clearly visible even from the railway carriage. The matrix is green shale. The pebbles are very varied, the following being the principal types:—quartzite, common; pinkish grit (Note 38, p. 235) of quartz and felspar; greenish felspathic grit; and green and grey hornstone. Of these, quartzite is the only ingredient which is certainly foreign to the slaty series; the others are such as are found in some part of the group. The conglomerate would then seem to have originated in contemporaneous denudation, such as is common in volcanic rocks, together with the wearing-down of a preexisting land composed of quartzite.

Interstratified with the conglomerate are beds of purple and green felspathic shale, with some bands of hornstone. The resemblance of these rocks to the St.-David's types is unmistakable.

The road-sections in this district display a prevailing north-west dip; but the more complete exposures in the railway-cuttings reveal frequent undulations, so that the thickness is not great.

A similar group, probably on the same horizon, is well displayed in the cuttings east of Bodorgan station, 6 miles south-west of Llangefni. The prevailing rocks are purple, green, and grey ashy shales, with some felspathic breccias. Conglomerates occur containing pebbles of felsite, in which microscopic examination (Note 39, p. 236) reveals a very interesting resemblance to modern lavas.

Associated with the shales at Llangefni station is a thick bed of quartzose grit, such as might have been produced by the denudation of an ancient quartzite.

Still following the strike to the south-west, we find the slaty series well exposed at numerous points on the coast from Bodowen round to the Aberffraw sands. On the shore near Bodowen, Llangefni conglomerate is underlain by grit. On the east side of Porth twyn mawr, it overlies slaty rock, and contains large unrounded pieces of it. The same conglomerate, repeated by folding, occurs at intervals as far as the Aberffraw sands.

Quartzite occurs in lenticular bands in pale-green slate west of Porth Cadwaladr. This association is also very common in Northern Anglesey.

Near, or at, the base of the slaty series of this district are several masses of quartz rock of obscure origin. The most prominent of these is the craggy hill * called Craig fawr, above Llangefni. It is a massive white rock, in which the quartzite structure is still apparent. It is surrounded by Carboniferous strata, and it probably formed an island in the Carboniferous sea. The same rock may be traced at intervals along the strike to the south-west. One conspicuous crag of it is seen at Bethel, north-east of Bodorgan station. I can only suggest that we may have in these bosses the remains of an ancient land, from which the Pentraeth gneiss derived its angular fragments, and the Llangefni conglomerate its rounded pebbles and its quartz grits.

3. *Cerrig-Ceinwen Slaty Group.*—These rocks lie to the north-west of the last group, with the same (north-west) dip; and as they present important lithological differences, they can hardly be repetitions.

North east of Cerrig Ceinwen, a little south of the Holyhead road, are green and purplish slaty beds. Some bands are calcareous; and the formation on the whole resembles the rocks forming the ridge at Wugan bach. Large nodules of jasper are abundant. Their origin is not absolutely clear; but I am disposed to regard them as included pebbles. The beds have a high dip to the north-west. On about the same strike to the south-west are pale green ashy bands. Close to Cerrig-Ceinwen church, to the north, are prominent ridges, composed of a greenish rock, so tough that it was difficult to obtain a specimen. It has a superficial resemblance to a greenstone, but is undoubtedly an indurated sedimentary rock, presumably an ash. It suggested the "greenstone" of Clegyr Foia, St. David's.

A fine exposure in a quarry west-south-west of Cerrig Ceinwen, on perhaps a little lower horizon than the jasper conglomerate, deserves attention. The rock is typical of the slaty series of Anglesey. In the field it appears as a pale green slate or indurated shale, sometimes faintly banded. Comparing it with some of the Charnwood slates (Note 44, p. 234), the only difference I could detect was that the Anglesey type displayed a slight lustre indicative of incipient metamorphism. It sometimes passes into a rock in which the alteration has been carried further, sometimes into a sort of hornstone. The dip is still to the north-west.

At Bod enlli we are apparently on the horizon of the jasper conglomerate. The conglomerate itself is not exposed; but we have limestone, purple slates, and green breccias and shales, not unlike those associated with the jasper.

* Coloured "greenstone" on the map.

Over a mile to the west-south-west, at Cerrig engan fawr, there is a considerable exposure of a very tough, green, ashy-looking rock, similar to the variety north of the church.

All the above rocks dip to north-west; but a little further to the west, at Ty'n-y-buarth, the beds dip to south-east. The strata at this locality are highly contorted on a small scale, and are very similar to the gnarled rocks east and south-east of Amlwch, the alteration, as in that district, having proceeded further than at Cerrig Ceinwen. In all other respects these altered rocks resemble the Cerrig-Ceinwen slates.

b. *Gneissic Series.*

The band of gneissic rocks is hardly a mile in width at Bodwrog, where it is separated from the Pebidian by a faulted strip of Palæozoic shale; but it gradually expands to a breadth of over two miles in the coast section on the south-west. The fault separating it from the slaty series runs from near Bodwina, north of the Holyhead road, in a south-south-west direction, losing itself under the sands of Aberffraw. On the west of the sands are nothing but schists; on the east are nothing but rocks of the slaty series. It will be necessary to describe two sections across this zone.

1. *Coast Section from Porth Nobla to Aberffraw Sands.*—On the coast, west of Porth Nobla, is a considerable exposure of greenish felspathic rock similar to the hälleflinta seen on the strike to the north-east, near Ty Croes. It appears to form an anticline. On Porth Nobla it clearly dips south-east, and passes gradually up into grey gneiss. To the west it presents but slight indications of stratification; but as we proceed eastward planes of separation gradually appear, which, at first obscure, become more and more distinct, till the rock is undistinguishable from a true gneiss. I have long since noticed an unbroken passage between hälleflinta and gneiss in the Wrekin; and Dr. Hicks has recorded the presence of an incipient foliation in the hälleflinta ("Arvonian") of St. David's. The grey gneiss soon passes up into quartzose gneiss, quartz-schist, and quartzite. These siliceous types, which are of much theoretical interest, occur in great force, and form the main part of the headlands of Mynydd baen and Pen y cnwc, which project between Porth Nobla and Porth Trecastell. On the west side of Porth Trecastell is a band of calcareous quartz-schist, or quartzose foliated limestone. The silicate appears to be talc or chlorite. There is a break in the section at the centre of the bay; but as the calcareous schist reappears on the east side, there can be but a slight break, if any, in the succession. Overlying the last-named rock is a considerable exposure of decomposed grey gneiss interstratified with bands of quartz rock, the whole being much contorted and broken. A greenstone dyke appears here. After a few undulations, the decomposed rock disappears, and ordinary white and grey gneiss, sometimes rather quartzose, dips steadily to the south-east for some distance. Then comes in the well-known green schist of the Menai type, which is continued to the Aberffraw sands. It is well

seen on Porth gwyfen with the normal south-east dip. On the shore, near the church, an undulation brings up grey gneiss. Then the south-east dip is resumed; but at Trwyn du, just before reaching the Aberffraw estuary, the beds turn up to the south-east, and a syncline is formed. The succession described is shown in fig. 4.

2. *Section on the Railway from Ty Croes to Bodorgan.*—The succession is substantially the same as the last; but it furnishes one or two additional facts. At Felin bont is the hälleflinta first noticed by Dr. Hicks, who rightly conjectured, as the last section proves, that it passed to the south-east beneath the schist at Ty Croes*, though he was in error in placing it above the granitoidite, which lies at the very summit of the gneiss series. West of Ty Croes quartzose schist is exposed in the road.

Coming to the railway-cuttings, we find to the east of the station a good section of grey quartzose gneiss (Note 34, p. 233) dipping south-east. This rock is one of the most prominent types seen west of Porth Trecastell. Grey and white gneiss are seen for more than a mile with the same dip. In the cutting from near Bodgedwydd to near Graig bach, the grey gneiss grows gradually darker and darker, and passes without a break into the dark green Menai type, which is continued to the end of the exposure. The average dip is 40° to south-south-east. Leaving the line, we find in a road-section north-east of Tre' Iddon that the dip of the dark schist has changed to the north-west. East of this point we come almost at once to the slaty beds and conglomerates of the newer series.

The railway-section is thus seen to agree precisely with the succession on the coast. In some points it is less complete; but it displays very clearly the passage of the grey into the dark schist, so well seen in the Menai anticline.

3. *Distribution of the gneissic Subdivisions to the North-east. Hälleflinta.*—This band gradually narrows towards the north-east, being cut out by the fault that brings the lower part of the gneiss series against the granitoidite; so that at Gwalchmai it is hardly visible, and at the section † north of the Holyhead road the grey gneiss is in immediate contact with the granitoidite. Some of the gneissic rocks of Gwalchmai display a transition towards the hälleflinta types.

Quartz-schist. This zone is not well exposed near Ty Croes. To the north-east it is seen at Melin Ddrydwy and Glan'rafon; but it may be best studied at Gwalchmai near the church, on the road to the south-west of the church, and on the Holyhead road. In the last locality the granitoidite is brought against it by the fault. The dip is to the south-east, except on the Holyhead road, where it is reversed. There is probably a broken anticline at this point. The prevailing

* I was at first disposed (Geol. Mag. March 1880, p. 123) to associate this hälleflinta with the granitoidite, since similar rock, together with quartz-felsites, is included in that group; but the coast-section has cleared up several difficulties.

† Geol. Mag. March 1880, p. 124.

type is a true quartz-schist, sometimes passing into a quartzose gneiss. As it was important to critically compare this rock with the quartz rocks of Holyhead and Bodafon Mountains, I have had four specimens cut; and Prof. Bonney appends full descriptions (Notes 25–28, p. 233).

Grey Gneiss. From the section east of Ty Croes station, this band may be traced to the north-east, forming the low ridge from Tal y llyn to Gwalchmai. Passing to the east of Gwalchmai church, it is well exposed about Bodwinafawr, and on both sides of the marsh (Cors Bodwrog) and pool. At Bodwrog church it is in contact with granitoidite, the quartz-schist having in its turn been cut out. In the ridge to the east of the church the gneiss is interstratified with a highly crystalline limestone, or calcite-schist (Note 51, p. 236). From the microscopic description it will be seen that this rock resembles the quartzose limestone of Porth Trecastell; and it is probably on the same horizon. The normal south-east dip is preserved as far as the old Holyhead road, north of the marsh; but near here a change takes place, and black Palæozoic shales come up to the granitoidite.

Dark Schist. This zone is not well seen north of the Holyhead railway. The fault which limits it on the south-east gradually cuts it out, so that east of Gwalchmai the slaty series approaches the grey gneiss. The gneiss is exposed at Pen bryncle, dipping south-east; and half a mile to the south-east, near the $\frac{12}{13}$ milestone on the Holyhead road, we find green slaty rocks with a north-east dip.

III. Central Zone.

This band extends across the island from sea to sea. It is the most complicated part of this broken and contorted area; but by steady attention to the lithology, assisted by some stratigraphical indications, clear results may be secured.

a. *Slaty Series.*

In following up the gneissic rocks towards Bodafon Mountain in order to ascertain the relation between the gneissic and quartz groups, I was surprised to find an area of slaty rocks between the two. At Plâs Llanfihangel dark gneiss and granitoidite dip to the south-west; and a little further to the north, at Ma'n-addwyn, felspathic shales dip as if they would pass below the gneiss. The rock is of a typical St.-David's type, and unquestionably belongs to the younger series. High up on the south-east slope of the mountain are similar rocks dipping south-east. The dips in both cases being *away from* the quartz rock, it was natural to infer that the shales rested immediately upon it. Further examination proved that such was not the case.

At the south-west end of the quartz ridge north-west of Ty'n-llidiart the flanking rock is a sort of hornstone, banded pink and green, of a common Pebidian type. Approaching the hill, the hornstone is seen to dip away from it to the south-west; but surmounting the low ridge made by the hornstone, the beds are observed to roll over and plunge directly towards the quartz at the very junction. A little further to the north, above the farm, the evidence of discordance is, if possible, still clearer. In the quarry is a good section of a greenish slaty rock, with the beds striking directly at the quartz forming the ridge at a distance of about 20 yards.

It is thus evident that the slaty series is faulted against the quartz group of Bodafon Mountain.

b. *Gneissic Series.*

1. *Bodafon Mountain.*—This mass cannot be brought into direct stratigraphical relation with the gneiss group, for the reasons just explained; but the lithological resemblance of this rock to the quartz-schist of Gwalchmai and Mynydd baen is so close as to render the correlation highly probable. In hand specimens some of the varieties are undistinguishable. Prof. Bonney, who was not aware of my views when working on the specimens, groups a typical variety (Note 29, p. 233) from the summit of the mountain with the Gwalchmai schists. The rock of the western ridge, which is a little more schistose, is also closely represented in the south-western localities. The inlier, surrounded by newer Palæozoic rocks, which lies to the south-east is precisely similar to the eastern part of the hill.

2. *Section between Llangwyllog and Llanerchymedd.*—The succession between these points is similar to that of the coast-section between Ty Croes and Aberffraw; but the granitoidite is wanting in the latter, and the dip is reversed, so that the two sections represent the two sides of a broken anticline.

The *granitoidite* occupies a large area south of Llanerchymedd. Round Coedana is a grey variety, rather small-grained. To the south, at Rhydgoch, it is much coarser, consisting of fragments of pink felspar in a matrix of smaller bits of quartz, felspar, and chlorite. The older geologists would have called it a porphyritic granite.

The *dark schist* is exposed about half a mile further to the south, at Glanrhyd, being the band of "greenstone" of the Survey. Prof. Ramsay originally suspected the metamorphic origin of this rock; and, after microscopic examination, Prof. Bonney is disposed to consider it a hornblendic gneiss, containing felspar, epidote, hornblende, and some quartz, the felspar being decomposed, and the whole a good deal "messed." Any obscurity arising from such an altered rock is removed if we follow the strike to the north-east. To the south-west of Graig llwyd there is a good exposure of hornblendic gneiss interstratified with granitoidite. The gneiss sometimes passes into hornblende-schist. The hornblende is well crystallized; and the alteration is very slight.

The *grey gneiss* is well seen about two furlongs south of Glanrhyd, in a quarry north of the stream. The dip is high, to the north-west; and the rock is of the ordinary type.

No rock is seen on the road for two or three furlongs to the south; but north of Llangwyllog church there is a slight exposure of *hälleflinta* too small to display dip. There is room for the *quartz-schist* between this rock and the grey gneiss; but I cannot affirm its presence.

3. *Area south-east of Paris Mountain.*—The gneissic rocks of this district are on the north-easterly prolongation of the strike of the central zone; and there is no doubt that they belong to the same series: the dip, the succession, and the prevailing rock-types are the same.

On the coast between Dulas Bay and the fault north of Porth lygan the succession is not satisfactory, owing to great disturbance. South of Porth lygan the shore is mainly occupied by sandstones and conglomerates, presumably of newer Palæozoic age, deposited on an eroded surface of gneiss, and sometimes wrapping round little promontories of the older rock. The prevailing dip is easterly. On Porth lygan the gneissic series is well exposed. Grey gneiss, dark-green schist, granitoidite, and quartzite (all the types which occur on the strike inland) lie in confused, contorted and shattered masses. At the north of the bay the rocks are less disturbed, and dip to the north-west. Black Ordovician (Lower Silurian) shales are faulted down to the north, resting, in a clear coast-section, against the granitoidite.

Between Llanwenllwyfo and Nebo the succession is more distinct. Thin-bedded gneiss is seen at several points north-west of Llanwenllwyfo and north of Plâs uchaf; the overlying green schist is well exposed around Rhos manarch; and the capping granitoidite, with associated schist-bands, forms the ridge between Nebo and Ty-Newydd, the whole dipping to the north-west. In two quarries south-east of Nebo there is well exposed a strong band of quartzite and quartzose conglomerate, similar to some of the masses on the coast. I have elsewhere* given reasons for believing that this is the equivalent of the quartzose conglomerate of Twt Hill; and I stated that in these quarries the rock is unconformably overlain by black shales of (at least) Bala age. If the shales are Tremadoc or Arenig, as Prof. Hughes has since maintained, the fact is still more strongly confirmatory of the Archæan age of the quartzite. As the point is important, I submit a section (figs. 5 & 6) from each of these quarries.

Since this quartz-rock is Precambrian, is conformably underlain and overlain by gneissic strata, and occurs on the coast in the closest association with gneiss and granitoidite, there can be no hesitation in referring it to the older Archæan series. It must not, however, be confounded with the quartz-schist of Bodafon Mountain, which is lower in the succession.

Granitoidite and dark schist are found along the ridge to the west, and at the base of Paris Mountain. I have not examined the latter locality; but Mr. Allport kindly allows me to use some notes made by him in May 1868. The numbers refer to specimens now in the British Museum.

"443. Fine-grained granite? South-east flank of Paris Mountain.

"444. Granite? 100 yards from last.

* Geol. Mag. March 1880, p. 118.

"338. Hornblende-schist, passing into a more compact rock (339), not schistose, or very slightly so; and this, again, into hornblende and felspar rock, very similar in appearance to that at Malvern (340).

"This is an interesting case, as the above varieties were taken from different parts of the same large block. As in Malvern rocks, epidote occurs near the joints. No. 340 might be called hornblendic gneiss; the felspar is well crystallized in many parts of the mass. In this place there is also hornblende and mica rock; and in some parts hornblende and felspar occur in separate layers. The granite has a gneissose structure; and to my mind the evidence is clear that the whole form a series of metamorphic rocks."

I am glad to quote confirmatory evidence by so competent a lithologist, and trust that it will be unnecessary to multiply refutations of the old "granite-vein" hypothesis.

4. *Structure of the Zone.*—For structural purposes it is necessary to include in this band the gneissic area between Ty Croes and Aberffraw. The whole forms a complex and shattered anticline. A central fault margins the granitoidite on the east from Caernarvon Bay to a mile north-east of Bodwrog; then it curves a little to the east, and, passing near Llangwyllog, leaves room for the underlying gneisses. The strata dip in opposite directions on each side of the fault. This dislocation thus appears to pass along the summit of the anticline; but it does so obliquely, permitting the south-east side of the arch to open out towards the south-west, and the north-west side to expand towards the north-east; so that we have an almost complete section between Llangwyllog and Llanerchymedd as we have between Porth Nobla and Aberffraw, but with the opposite dip.

The large area occupied by the granitoidite may seem to require explanation. As this rock rarely exhibits bedding, its relations are frequently obscure; but, fortunately, in the district between Gwalchmai and Llechyn farwy the dark Holyhead schist, which immediately underlies it, is brought up by repeated undulations. Near Gwalchmai, for example, the granitoid rock dips north-west; but to the west it is thrown off in opposite directions in the Craig-yr-allor anticline. The granitoidite is, then, a band of no great thickness, repeated by contortions. There is also evidence of repetition by faults.

The generalized section (fig. 1) represents the relations of the principal rock-groups in Anglesey.

IV. Northern Area.

This district is bounded on the south by the curved fault which, starting from near Carmel's Point on the west, passes round by way of Llanfflewin and Paris Mountain to the east coast at Porth-y-corwg. The rocks are very much contorted and broken; but there appears to be, on the whole, an ascending series from the fault to the north coast. The dip is generally to the north; but on the west it is to the north-east.

1. *Volcanic group of Paris Mountain.*—The chief types of this

ridge are a felspathic breccia and a compact felspathic rock like hornstone; but both varieties are quite distinguishable from any other rocks in Anglesey. At the east end of the hill, by the Pensarn chapel, the breccia is well exposed. The fragments, some of which are a yard in diameter, are a very compact felstone; and the matrix is a sort of greenish ash. The rock, as a whole, reminded me of the compact breccias at Clegyr Bridge, St. David's. Prof. Bonney has since examined a slide; and he is of opinion that it exhibits both perlitic and fragmental structure and is in all probability a rhyolitic ash. The dip of the series is to the north, agreeing with that of the adjoining slaty group. About 100 yards to the east of the chapel, and therefore on the same strike, is a knoll composed of a pale-green and purple rock, very compact, almost like jasper. Under the microscope (Note 53, p. 236) it is seen to be a trachyte, probably from a lava-flow, and is, in Prof. Bonney's judgment, as modern in its appearance as the rock composing the enclosed pebbles near Bodorgan. The purple variety is not unlike some of the flinty felstone common in the Precambrian of Shropshire. From lithological characters the Archæan age of this group appears not improbable, though it must be conceded that it does not resemble very closely the volcanic group south of Bangor. Field work throws little light upon the problem. On the north side the ridge is bounded by a fault; and at the base of the southern escarpment black shales seem to pass conformably under the volcanic group. The two rocks appear within three or four feet of each other, dipping in the same direction into the steep face of the hill. There are, however, no signs of a passage between the black shales and the compact felspathic rock. The appearance of conformity might be produced by faulting, accompanied or followed by lateral pressure; and there are abundant proofs of both in the district; but, under the circumstances, I hesitate to include this group in the slaty series.

2. *Chloritic Schists of Mynydd Mechell.*—This group is the "foliated grit" of Ramsay. In the field it has the appearance of a quartzose grit, with chlorite covering lamination surfaces; but Prof. Bonney, after microscopic examination, regards it as a true schist (Note 45, p. 234) of the Holyhead type, though he admits that the chloritic constituent is "rather minute." These rocks are much contorted, and are frequently penetrated by dykes of felstone and dolerite running with the strike. At a higher horizon, at Cas Clock and west of Rhos-y-pill, the rock is an undoubted schist with silvery lustre (Note 46, p. 234). Some of the strata north-east of Paris Mountain are not unlike this schist, as may be seen at Cerrig, on the Amlwch road.

It is important to observe that Prof. Bonney agrees with me in recognizing (Notes under C, p. 234) a difference between these schists and those of the gneissic districts; but in such a broken country it is difficult to prove that these rocks should go with the slaty series. My reasons for so associating them are the following:—

(1) The rocks are not uniformly foliated. To the west of Cas Clock, for example, chloritic schist is overlain in the same quarry

by hard grits. In the same neighbourhood are bands of hornstone, similar to ordinary Pebidian types, associated with schist.

(2) These rocks appear to pass up through less altered varieties into slightly metamorphosed grits and shales, as seen south of Llanfechell and in localities to the east.

(3) The alteration is not carried so far as is usual in the older series.

(4) In the undoubted slaty districts, as west of Cerrig Ceinwen, the rock frequently undergoes partial metamorphism, and bands occur which might almost pass for true foliated schists.

(5) This area is scored with intrusive dykes. I do not suppose that these are the cause of metamorphism; but they indicate the proximity of a source of heat, which may have been concerned in the change.

3. *Llanfechell Grits.*—The altered rocks of Mynydd Mechell appear to pass to the north into a series of green grits, well exposed round Llanfechell. This rock has undergone much alteration, to which probably the colour is due. Microscopic examination (Note 47, p. 234) brings to light the important result that it is "almost certainly derived from the older gneissic and schist rocks of this region of North Wales." These grits are also seen on the strike to the south-east near Bodewryd.

4. *Rhosbeirio Shales.*—West of Rhosbeirio church, and in a quarry near the farm, are very interesting exposures of felspathic rocks of the true St.-David's type. These shales are soft, well laminated, and fine-grained; but here and there are thin seams of grit like the variety just described. While the body of the rock is but slightly altered, the gritty bands have a very schistose look. The prevailing colours are pale green and purple; but there are also some beds of a soft yellow shale, like a common variety in North-western Anglesey. The dip is to the north at 30°. Under this group, at Nant-y-cyntin, slaty beds of a more altered character, intermediate between these shales and the Cas-Clock schist, are seen.

5. *Sharply contorted Group south-east of Amlwch.*—At Crogan goch and on towards Llaneilian are exposed the remarkable rocks described and figured by Prof. Ramsay. The foliated structure (Note 49, p. 234) of these slaty-looking beds is not very evident to the naked eye. Similar rocks compose the tongue-shaped promontory of Point Ælianus; but sometimes contortion is wanting. At the base of the promontory the beds are gritty and partially altered (Note 48, p. 235).

6. *Amlwch Slates and Cemmaes Limestones.*—South of Amlwch, near Crogan goch, the last group, with the intervention of an ashy band, is succeeded by uncontorted pale-green chloritic slaty beds (Note 50, p. 235), which are continued to the coast and all along the west side of Bull Bay to Ogo' goch. The dip is steadily to the north at a moderate angle; and the thickness must be considerable. Towards the west, on Porth wen, bands of limestone and quartz-conglomerate come in; and further west, on Cemmaes Bay, limestone and quartz rock predominate over the slaty beds. I am not certain

that the Amlwch and Cemmaes groups are on the same horizon; but the evidence appears to point in that direction. The limestone (Note 52, p. 236) is very similar to a rock at Llanfaethlu; and the associated slaty beds are alike in both localities; but it would be rash to correlate the groups.

The northern area (omitting Paris Mountain) is thus seen to consist of chloritic schists, felspatho-quartzose grits, felspathic shales, chloritic slates, quartz-conglomerates, and grey limestones, with some limestone bands on more than one horizon. In such a shattered district a true succession can hardly be indicated. North of Paris Mountain some of the horizons are probably faulted out of sight, and it is difficult to correlate the rocks of this district with those further west. Most of the groups appear to pass into each other, either vertically or laterally; and I cannot avoid the conclusion that they all belong to the same epoch.

V. North-western Area.

In Western Anglesey are two well-marked groups of strata, which I regard as the equivalents respectively of the Gneissic and Slaty series. They are brought together by a fault.

Porth-y-defaid Fault.—This dislocation is situated on the west coast, about midway between the northern and southern extremities. It is well seen on the shore, striking inland to the east. Greenstone is erupted along the line of junction, and alters the strata for a short distance on each side. South of the fault are thoroughly crystalline quartzo-micaceous and chloritic schists dipping north-west; while close at hand on the north side green ashy shales dip north-east. This fault is the boundary between the two series; for true schists with a south-west strike occur everywhere to the south, while a comparatively unaltered group, with a prevailing northerly dip, stretches right up to the north-west corner of the island.

Section from the Fault to Pen bryn'r Eglwys.—Proceeding northward, we find at Trefadog ashy shales dipping north-east. In the quarries north of Llanfaethlu church is a good section of grey limestone and pale-green ashy slate with easterly dip. The former is compact, and apparently as unaltered as any Palæozoic limestone. A careful search revealed no trace of fossils. The slaty rock is of a common Anglesey type; and the whole group is like the Cemmaes series. About Llanrhyddlad exposures are numerous. At Porth Swtan, on Church Bay, is a considerable thickness of yellowish felspathic slate and breccia. The dip is north-east, with slight contortion on a small scale. Higher beds are seen in quarries at Rhyd Ngharad; the rocks are brecciated in part and very felspathic. Greenish colours predominate. One variety, a pale-green slate, contains cubic pyrites. On about the same horizon, at Ogo Lowry, are green brecciated rocks more highly indurated.

The district between Ogo Lowry and Penbryn 'r Eglwys is one of the most faulted parts of the island; the section consists of alternations of Archæan and Palæozoic rocks, repeated by faults, and dipping to the north. The wedges of dark shale let in amongst the older group are very clearly seen in the sea-cliffs. The younger shale, of course, frequently appears to pass under the felspathic series. Such facts suggest great caution in trusting to dips in areas where the faulting is not clearly seen. The lithology here, as generally in Anglesey, is the true guide. The Precambrian chiefly consists of felspathic breccia. The fragments are usually of similar composition to the matrix; but some are of quartzite. The felspathic fragments weather out sharply where the cliffs are washed by the spray. On the whole this rock strongly suggests the breccia near Nun's Well, St. David's. Good exposures are seen at Yynys y fydllyn, Porth yr hwch, and west of Pant yr Eglwys. The thickness, owing to such frequent faulted repetitions, probably is not great.

The section at Pen bryn'r Eglwys is of much interest. In this great headland, which juts out at the north-west corner of Anglesey, are rocks which are described in the section of the Survey Map as "gneissic rocks pierced by granite veins;" and these are represented as passing on the south into "metamorphic foliated rocks." The latter are the felspathic shales and breccias already noticed. The description of the former also requires modification.

The breccias pass up into the southern slope of the headland, where they are succeeded by a band of quartzite. This is overlain by a considerable thickness of greenish felspathic beds of ordinary Pebidian type and not much altered. The highest ridge of the promontory consists of this rock. Following these strata across the strike to the north, they are seen gradually to change, the rock putting on a glazed aspect, and mica appearing in small quantities on the lamination-planes. This altered material soon passes into thoroughly foliated gneiss and granitoidite.

It was rather startling to find true metamorphic rocks associated with comparatively unaltered felspathic beds of the newer series. The granitoidite is very similar to that of the older gneiss; and my first impulse was to refer it to that group. In such a shattered district as Anglesey, especially in such an area as its north-west corner, a faulting-up of the older series seemed not unlikely. But, after careful examination, I found it impossible to accept this supposition. The transition between the unaltered rock and the schists is gradual and complete. A close comparison furthermore revealed lithological distinctions between the gneiss of the two series, the most important of which is a difference in the colour and lustre of the mica.

The cause of metamorphism was not apparent. The "granite veins" of the Survey are probably the granitoid bands in the gneiss. Some quartz veins running across the cliffs may have suggested the intrusion of granite. As this metamorphosed mass occurs in the neighbourhood of the Mynydd-Mechell schists, the alteration in both cases may be due to the same general cause.

VI. Western Area.

All the rocks south of the Porth-y-defaid fault and west of the Palæozoic area belong to the older series.

1. *The Mainland.*—This district is chiefly occupied by green chloritic schists (Note 37, p. 234) similar to the rocks described from the Menai anticline, Aberffraw, Craig yr allor, and east of Paris Moun-

tain. The dip is usually to the south-east; but the beds frequently roll over to the north-west, as may be seen south of Porth twyn-mawr, and at Caer ceiliog on the Holyhead road. There is no doubt that these schists represent the dark green band which in the central zone underlies the granitoidite.

2. *Holyhead District.*—Chloritic schists are well seen at many points in and round the town. A typical specimen from Porth felin (Note 36, p. 234) is of the same character as the schist at Porth y defaid. The strike is to the south-west; and undulations are numerous. These rocks are separated from the quartz group by faults: one, on the south-west, runs from the south coast, at Porth y corwgl, to the south end of Holyhead Mountain; and another, on the north-west, lies along the south-eastern base of the mountain and cuts the coast at Porth yr Ogof.

Porth-yr-Ogof fault.—Prof. Ramsay* states that the "quartz rock" dips under the "foliated schists;" and he gives a section in support of his opinion. This view would have greatly simplified my work; but on visiting the spot I was disappointed to find that the two groups were brought together by a fault. There was a notch in the cliff; on one side was quartz rock, and on the other green schists (Note 35, p. 234), with no signs of a passage. The break was filled in with fallen rubbish. It was very fortunate that this dislocation was discovered, as it compelled me to seek the true succession elsewhere.

Holyhead Mountain.—The microscopic examination (Note 31, p. 233) of a typical specimen of the quartz rock from the great quarry shows that it is a true quartz-schist of the same type as the Bodafon, Gwalchmai, and Mynydd-baen quartz groups. The structure of the mountain is interesting. Ascending the south-east slope, separation-planes are seen to dip to the north-west at about 80°; but on the north-west side the dip changes to south-east at the same angle. The planes are not close and even, as in slaty cleavage, but they cause the rock to split in large thick flat flakes. This difference is doubtless due to the coarseness of the material; and the planes must represent true cleavage. The cleavage-strike agrees with the strikes of the contorted bedding and of the ridge.

The Holyhead district is thus brought into clear comparison with other parts of Anglesey. The chlorite-schists undoubtedly represent the dark schist which underlies the granitoidite in the central zone; and the quartz-schists may with the highest probability be placed on the same horizon as the foliated quartz rocks of Bodafon and Gwalchmai. The absence of the grey gneiss is easily explained. On both the west and south the junction between the quartz and chloritic groups is a fault; but the two formations dip in the same direction, and the downthrow is apparently on the side of the chlorite-schist. As the latter group is repeated in numerous shallow curves, there is no reason why the grey gneiss should appear at the surface, as it does amidst the deeper undulations of the Menai anticline.

* Geology of North Wales, p. 183.

The chloritic rocks of this area are rather more quartzose than in most Anglesey localities; but they resemble some of the varieties in Mynydd Llwydiarth, and there are indications in both districts that a source of quartz-derivation was not far distant.

3. *Rhoscolyn District.*—The south-eastern half of Holyhead Island is similar in structure to the Holyhead area; but the rocks are affected by an upheaving force to the south, so that the prevailing dip is to the north. The green schists, which occupy the chief part, need no further description. The southern fault, which separates the quartz and chloritic groups south of Holyhead, passes under the sea, and holds the same relation near Rhoscolyn. It is first seen near Bwa du, and again appears on the coast to the south-east at Borth wen, passing in its course near Rhoscolyn church, where the quartz-schist (No. 32, p. 233) is exposed, dipping northerly. A few yards to the north the chloritic group dips in the same direction, at about the same angle. At Bwa du the junction is well seen, both series dipping northerly, the green schist at a lower angle than the other. The quartz group forms an elevation, Mynydd Rhoscolyn, as is usual in Anglesey.

At Borth Saint, south of Bwa du, the contortion is intense. There is evidence, from the folding of quartz veins, that the rock has been squeezed to one fourth of its original bulk. At one spot there is a very curious specimen of ripple-mark, distorted so as to be almost unrecognizable. Quartzite dips to the north, and is underlain by soft schist. The under surface of the former overhangs, and is covered with rounded projections, which are evidently the squeezed casts of ripple-marks. The schist was the mud which received the impressions of the ripples; and the quartzite represents the sand which covered in and preserved the marks. I have elsewhere* figured and described the above phenomenon. It is important to record ripple-marks in so ancient a formation.

South of the last locality is a considerable thickness of chloritic quartz-schist (Note 33, p. 233).

B. Summary of Results.

I. Distribution of the Rocks.

[See Map (Pl. VIII.) and Fig. 1.]

a. *Gneissic Series.*

1. *Geographical Distribution.*—This series occupies the greater part of the Menai anticline. It reappears west of the Llangefni slaty area, and forms the whole of the central zone, except the faulted mass south-west of Bodafon Mountain. It then reemerges west of the Palæozoic, and covers Western Anglesey south of the Porth-y-defaid fault. About three fifths of the area coloured "altered Cambrian and Silurian" consists of gneissic and schistose rocks.

* 'Science for All,' part xxxi. pp. 203 and 205.

The *hälleflinta* forms a band extending from Porth Nobla to near Gwalchmai. It is probably represented north of Llangwyllog.

The *quartz-schist* extends on the strike from Mynydd baen to Gwalchmai. It may occur in its place north of Llangwyllog; but it emerges in the craggy mass of Bodafon Mountain and in the small inlier to the east. In Western Anglesey it forms the elevations of Holyhead Mountain and Mynydd Rhoscolyn.

The *grey gneiss* is brought up through the dark schist on the western side of the Menai anticline at Gaerwen and east of Pentraeth. In central Anglesey it runs from near Porth Trecastell to north-east of Bodwrog, reappearing soon after on the opposite side of the anticline north of Llangwyllog, and further to the west in the Craig-yr-allor anticline. To the north-east it is seen in the area south-east of Paris Mountain.

The *dark schist* occupies the greater part of the Menai anticline. It emerges west of the Llangefni "syncline," but is gradually faulted out towards Gwalchmai. On the opposite side of the central anticline it forms a band as far to the north-east as Plâs Llanfihangel, and is brought up through the granitoidite in the oval dome of Craig yr allor. It also occurs south-east of Paris Mountain. In Western Anglesey it constitutes the schistose area south of the Porth-y-defaid fault and north of the quartzose masses.

The *granitoidite* is the "granite" band of the Survey. The details are inaccurately laid down in their map at many points; but little theoretical importance attaches to these errors. There are slight traces of this rock on the west side of the Menai anticline.

2. *Stratigraphical Distribution.*—One of the most difficult problems in Anglesey was to make out the succession of the subdivisions of this group. In no single section, owing to the faulting, is the series entire; but the subdivisions are recognizable by their lithological characters; and by comparing localities the fragments are pieced together into a complete succession. The facts will be best expressed in the following table, the groups being taken in descending order:—

	1. Holyhead.	2. Craig yr allor.	3. Coed-ana.	4. Dulas Bay.	5. Ty Croes.	6. Menai.
Granitoidite ...	...	*	*	*	...	Traces.
Dark schist ...	*	*	*	*	*	*
Grey gneiss ...	...	*	*	*	*	*
Quartz-schist ...	*	...	?	...	*	
Hälleflinta ...	...	...	?	...	*	

The star indicates the existence of the subdivision in the locality at the head of the column. By comparing 5 with 2, 3, and 4, it will be seen that two groups are common to the four areas; and they serve to link together the lowest and highest subdivisions.

The series is probably complete in 3; but in running the section I could get no exposure between an obscure opening of hälleflinta and the grey gneiss, and I had not time to search beyond the highroad.

b. *Slaty Series.*

This group occupies four areas, viz. the small mass south-west of Pentraeth, the east side of the Llangefni "syncline," northern Anglesey, and the western division north of the Porth-y-defaid fault. The chief facts are thus summarized:—

(1) *South west of Pentraeth* (Wugan-bach ridge).
Slaty and dolomitic rocks.

(2) *Llangefni district.*
Slates (some hypometamorphic *), grits, green conglomerates, purple and green shales, hornstone, calcareous beds.

(3) *Northern district.*
Chloritic schists, altered grits, green and purple shales, slates (some hypometamorphic), quartz-conglomerates, limestones, hornstone.

(4) *North-western district.*
Yellow felspathic shales and breccias predominating, quartz-conglomerates, pale-green slates, and limestones.

I am not prepared to submit a scheme of the succession. The rocks of area 1 are not unlike some of those near Cerrig Ceinwen in area 2. Comparing 2 and 3, the rocks are similar as a whole; but the green conglomerate, so conspicuous in 2, is not seen in 3, while the quartz-conglomerates and grey limestone of 3 do not appear in 2. Portions of 3 are also altered to schist, while in 2 the transition into foliated rock is rarely complete. The felspathic breccias of 4 do not certainly occur in any of the other areas; but its quartz-conglomerates, slates, and limestones are similar to those of 3. The interesting Rhosbeirio shales in 3 have less complete representatives in 2, but are fully exhibited in 4.

The rocks of these four areas, though geographically isolated, are closely connected by their mineral and petrological characters, and I have no hesitation in placing them all in the same group. Should the chloritic schists of the north be separated from the newer series, it will not materially affect my general conclusions. The same remark applies to the small patch of gneissic rock at Bryn 'r Eglwys.

II. Evidence of Age.

a. *Relations to Palæozoic Groups.*

Gneissic Series.—It is not necessary to recapitulate the evidence for Precambrian age. The sections in the quarries near Nebo would alone be sufficient to remove all doubt.

Slaty Series.—These rocks do not clearly underlie any part of the Cambrian; they are, indeed, overlain by a purple conglomerate on the north coast, west of Tor llwyn. The pebbles of this rock are a

* The term "submetamorphic," used by some authors, is objectionable on grammatical grounds.

purple quartzo-felspathic grit; but I have no certain proof of its age.

The Precambrian age of the series may be inferred from included fragments. The rocks west of the granitoid zone are shown by the fossils collected by Prof. Hughes to be Tremadoc and Arenig. In the conglomerates west of Llanfaelog, which appear to be of at least equal antiquity, a large proportion of the pebbles are certainly derived from the Slaty series, pale green and purple hornstone and slate being the most common. It is also worthy of notice that the Harlech conglomerates of Caernarvonshire contain fragments of green and purple slate *, which must therefore be Precambrian and of no distant source of derivation.

The relations of these series to the Cambrian rocks in contact indicate the same result. At numerous points the two groups are brought together by faults; but while the Slaty series is generally more or less altered, the Cambrian shales are quite unchanged, and I have never observed the slightest indications of a passage between the two, the line of demarcation being always clear and sharp. The Slaty series must therefore have undergone partial metamorphism before the Cambrian period, otherwise it is difficult to see how the Cambrian rocks could have remained unaltered.

The black shales in some localities dip as if they would pass under the altered series; but at many points the latter also appear to pass beneath the former. In such a shattered district this evidence is worth nothing in either case, unless an unbroken sequence can be proved.

I am not prepared absolutely to deny that true Harlech rocks occur in Anglesey. There are beds, especially near Llangristiolus, which lithologically do not appear to be very distinctively Precambrian; but, as stratigraphically they are closely associated with the Slaty series, it is safer to place them in that group.

b. *Relations to each other.*

In all parts of Anglesey the junction of the two series, whenever they are in contact, is a fault. In the east and centre they generally strike in the same direction; but in the north-east (near Paris Mountain), at the base of Bodafon Mountain, and in the western district, as seen north and south of the Porth-y-defaid fault, the strikes are discordant, sometimes approaching a right angle. The much more intense metamorphism of the gneissic series would seem to point to a greater antiquity. Some additional light is thrown upon the subject by the microscope. Prof. Bonney, in note 47 (p. 234), already noticed, is decidedly of opinion that the Llanfechell grit, a characteristic variety of the newer rocks, is derived from the older series.

c. *Relations to other Areas.*

(1) *Caernarvonshire.*

Comparing the *Slaty series* with the Bangor group, the re-

* Bonney, Quart. Journ. Geol. Soc. vol. xxxv. p. 311.

semblance, it must be confessed, is not very close. Both formations are largely of volcanic origin; but the felspathic materials of the Anglesey rocks are derived from a more distant source, while the frequency of quartzite pebbles indicates the proximity of land not covered by volcanic products.

The *Gneissic series* would appear to be closely related to the granitoid rock of Twt Hill. As the normal position of the dark schists is below the granitoidite, there seems to be no reason to doubt that the green schists on the Anglesey side of the Menai Straits pass conformably beneath the Twt-Hill beds. The post-Carboniferous fault on the west side of the Twt-Hill ridge might not materially affect the true relations of the older subdivisions.

(2) *St. David's.*

Slaty Series.—The lithological resemblances between this group and the St. David's Pebidian are numerous and striking. The varieties whose Pebidian facies is most marked are the pale-green, purple, and yellow felspathic shales of Rhosbeirio, the felspathic breccias north of Llanrhyddlad and east of Bodorgan station, the tough green rock at Cerrig Ceinwen and Cerrig-engan fawr, porcellanitic bands near Llangristiolus, and hornstones of many localities. The slaty beds are less distinctively of St. David's type.

Gneissic Series.—The Anglesey granitoidite has been compared by Messrs. Bonney and Hicks with the St. David's Dimetian. If this correlation be conceded, the entire Anglesey series, from the hälleflinta upwards, must go with the Dimetian. But it must be admitted that the two groups present important differences. At St. David's the Dimetian is represented by a great thickness of granitoidite and quartzite; whereas in Anglesey the similar band is much thinner, and is underlain by a considerable thickness of gneiss and other schists.

(3) *Shropshire.*

The felspathic slaty beds of Lilleshall Hill are hardly distinguishable from some of the Anglesey rocks. The Lilleshall group is probably higher than the Wrekin volcanic rocks, which have many points of resemblance to the fragmental group south of Bangor. The purplish ash of the Wrekin, for example, is very similar to the grit at Bryn llwyd. Nothing certain, of course, can be inferred from such facts; but it is at least worthy of consideration, and the suggestion may be a guide in further inquiry, whether the Anglesey Pebidian may not represent a higher horizon than the Bangor group. Some of the gritty and slaty rocks of the Precambrian ridges east of Church Stretton also display affinities with the Anglesey series.

It is worthy of note that the Charlton-Hill conglomerate, an undoubted part of the Wrekin group, contains, amongst enclosures from the Malvern series, pebbles of rocks which more closely resemble some of the gneissic and quartzose types of Anglesey.

(4) *Charnwood.*

The slaty rocks of Anglesey are nearer in their lithological characters to the Charnwood slates than to any other formation with which I am acquainted. The resemblance was very marked even in the field; but in the case of a homogeneous rock like slate, the microscope is of special value, and Prof. Bonney's examinations (Notes 42, 43, 44, pp. 234, 235) are strongly confirmatory of my opinion.

Conclusions.

1. In Anglesey there are two Archæan groups, the Slaty and the Gneissic.

2. The Slaty series is composed of slates, shales, hornstones, grits, conglomerates, limestones, and chloritic schists, in which no definite order has been positively ascertained. The Gneissic series is divided into five groups, in which the following descending order is invariable, viz. granitoidite, chloritic and hornblendic schists, grey gneiss, quartz-schist, and hälleflinta.

3. The Slaty series is occasionally foliated, but is usually in a partially altered state: the Gneissic group is thoroughly metamorphosed.

4. The Slaty series has closer lithological affinities with the St.-David's volcanic group, the Charnwood rocks, and the Lilleshall series than with the Bangor group.

5. The Slaty series is undoubtedly Pebidian: the Gneissic series may with some probability be referred to the Dimetian.

APPENDIX.

Notes on the Microscopic Structure *of some* Anglesey Rocks. By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

In the following notes I shall endeavour to avoid repetition by grouping together those specimens which in some important characteristics have a general resemblance one to another. I may add that, as the purpose of my examination was petrological rather than mineralogical, I have not felt bound to spend much time in endeavouring to ascertain the exact species of some microlithic minerals which are accidentally present in one or two of the slides.

A. *Quartz-Schist Group.*

Nos. 25–29, 31–34.

This group consists of a series of schistose rocks, in general highly metamorphosed, in which quartz is the most important constituent, associated with micaceous or chloritic minerals, ferrite or opacite, and more or less felspar.

The fragmental origin of most of these specimens is indubitable; but with regard to numbers 25 and 27 it is less easy to be quite sure. Their structure comes nearer to that of some microcrystalline felsites; but still I believe that I am right in ranking these also among the altered clastic rocks.

25. (Gwalchmai, p. 218.) Contains numerous grains of quartz of

rather irregular outline in a finely granular and rather earthy-looking matrix—most probably the result, in the main, of the decomposition of rather imperfectly crystallized felspar, which consists now of an admixture of earthy dust, doubly refracting clear microliths, and minute scales of mica or chlorite. The quartz grains show an indistinct banded order, and contain many minute cavities. The rock appears to have been brecciated more than once *in situ*. The older cracks are mainly filled up by quartz, the newer by calcite with a little chlorite. In one part of the slide the faulting of an older vein and subsequent infiltration of a newer one is very clearly shown. Macroscopically the rock has a resemblance to the Treffgarn hälleflinta, but under the microscope it is more gneissic.

26. (Gwalchmai, p. 218.) Is certainly of fragmental origin, showing stratification foliation. The quartz grains have fewer inclusions; there is felspar much as before, and a fair quantity of mica; most of this is of a very pale golden-yellow colour, is feebly dichroic, and gives brilliant tints between the Nicols; the rest is dull green, probably an alteration produced after biotite. Some granular matter as above.

27. (N.W. of Gwalchmai, p. 218.) More resembles 25, but is more compact. I think that it, too, is of fragmental origin, and is probably the result of the metamorphosis of a fine quartzose silt.

28. (N.W. of Gwalchmai, p. 218.) Is certainly fragmental, consisting of quartz with a fair amount of chlorite, some white mica, and a few grains (probably fragmental) of a closely twinned plagioclastic felspar.

29. (Summit of Bodafon Mountain, p. 219.) Is a quartz-schist with a fair amount of ferrite and minute chlorite (?).

31. (Holyhead Mountain, p. 226.) Also a quartz-schist with a fair amount of a pale-green mica, as above, the ground-mass consisting of this mineral with agglutinated very minute grains of quartz. In this are scattered quartz grains of larger size up to about 0″·03 diameter, clearly of fragmental origin, some having a secondary deposit of quartz on their edges. Minute cavities are common in these grains, and one or two contain some dark hair-like microliths, a grain or two of epidote, and possibly one of tourmaline.

32. (Rhoscolyn church, p. 227.) Also a quartz-schist resembling the last, but more uniform in structure; the same adventitious minerals as in the last.

33. (S. of Borth Saint, p. 227.) Another quartz-schist with rather more mica and chlorite, a few grains of felspar, and the same adventitious minerals. Numerous grains of a granular earthy mineral (? an epidote).

34. (Cutting E. of Ty Croes, p. 217.) Quartz and a white mica are the most conspicuous minerals, with an occasional grain of felspar; but a sort of granular paste in which these are imbedded, consisting of microliths of white mica and other minerals, may in some cases have replaced a felspar constituent. The rock is much altered, but, I suspect, still retains in its large grains traces of its original fragmental structure.

B. *Chlorite-Schists.*

A group of highly altered, distinctly foliated rocks, consisting mainly of rather minutely crystalline chlorite and quartz. To this belong Nos. 35–37, 45, 46, 49.

35. (Porth yr Ogof, Holyhead, p. 226.) Contains very numerous rods and granules of a black mineral, perhaps magnetite, with a little sphene or staurolite; it exhibits beautiful contortions.

36. (Porth felin, Holyhead, p. 226.) Foliation less marked; a considerable amount of ferrite is present. Original structure perhaps less uniform than in the last.

37. (Porth y defaid, p. 225.) The same remark applies to this specimen also, but its foliation is more marked. A vein of quartz and calcite.

45. (Melin pant y gwyda, p. 222.) The same; chloritic constituent rather minute.

46. (Cas Clock, p. 222.) Highly altered and markedly foliated.

49. (Crogan goch, p. 223.) The same; chloritic or possibly micaceous constituent extremely minute; beautifully foliated and contorted.

In this group, as a rule, it is more difficult to identify with probability any original constituent of the rock, owing probably to differences in chemical composition and size of the materials. Some of the quartz grains in 37, 45, 46 may, however, be original.

C. *Slaty and other not highly altered Rocks.*

In this group there has, indeed, been a certain amount of alteration, but it is only what may be termed micromineralogical. The original fragmental character of the rock is still distinct; the newer products are either extremely minute or such as result rather from *decomposition* than from *recomposition.* The alteration, in short, is of a kind which we commonly meet with in the earlier Cambrian or latest Precambrian rocks, not in the gneisses, in the conspicuously foliated schists, and in the most highly metamorphosed quartzites. Its members, then, are, as a rule, either much more modern than those previously described, or selective metamorphism must have operated upon the latter to a rather unusual extent.

43. (S.E. of Cerrig ddwyffordd, pp. 214, 232.) One of the flinty argillites or indurated imperfectly cleaved slates. Under the microscope the slide consists of a brownish-grey earthy-looking material interspersed with minute specks of quartz, felspar, and micaceous or chloritic minerals, whether original constituents or of secondary origin it is in many cases difficult to say. The "stripe," however, is well indicated, and the specimen in no important respect differs from many examples that I have examined from Charnwood and other localities where the rocks are approximately of Cambrian age.

44. (W.S.W. of Cerrig Ceinwen, pp. 215, 232.) A similar rock of slightly coarser material and a little more distinctly cleaved. Among the constituents are many scales of a strongly dichroic green mineral with a marked wavy cleavage—chlorite or some member of the provisional viridite group, probably the result of alteration of a magnesia-iron mica fragmentally present.

47. (Llanfechell, p. 223.) A coarser fragmental rock with a rather

"streaky" structure, not unlike some of those which occur in the Borrowdale series, containing numerous microliths of the viridite group, some being certainly chlorite. The aspect of the rock suggests that it has undergone considerable pressure. Many of the imbedded fragments are from about 0″·03 to 0″·06 in longer diameter. Among them quartz, felspar, altered biotite (?), and a chloritic quartz-schist may be recognized, detrital materials almost certainly derived from the older gneissic and schist rocks of this region of North Wales. Other fragments of a less certain character are present, with grains of decomposed ilmenite or magnetite and of epidote, which perhaps has replaced some other mineral.

48. (Base of Point Ælianus, p. 223.) A rock of a generally similar character; but, as the fragments are smaller, their nature (except in the case of the quartz) is less easily ascertained; the whole rock also seems slightly more altered than in the last case.

50. (Coast N.W. of Amlwch, p. 223.) The materials are more homogeneous than in the other cases; small greyish clustered granules frequent, and a vast number of microliths of a green mineral (chlorite?). These are very likely of secondary origin, but I consider the rock a true slate, and not a schist.

42. (S.E. of Cerrig ddwyffordd, p. 214.) A fine grit with much of the fibrous green (? hornblendic) mineral which I have often observed in the Charnwood rocks developed among the finer materials; the larger fragments (generally rather angular) are chiefly quartz, felspar (orthoclase and plagioclase), and a minutely microcrystalline or cryptocrystalline rock, much resembling bits of an acid lava. From certain minute peculiarities, I have strong suspicions that all three of these constituents have been derived from rocks of volcanic origin.

38. (Fragment in Llangefni conglomerate, p. 214.) A grit, consisting of subangular and rolled grains, mostly quartz, in a fine quartzose or quartzo-felspathic matrix. It is difficult in the case of rocks of this character to draw an inference as to their age and amount of metamorphism; but I believe that I am right in grouping it with the probably more modern series.

D. *Granitoid Gneiss.*

Of this rock there is one specimen from Pen Bryn yr Eglwys not at all in a favourable condition for microscopic examination. It resembles the group of coarse granitoid gneisses similar to those which I have examined from the neighbourhood of Llanfaelog rather than a true igneous rock. It consists of quartz with many minute enclosures, two felspars much decomposed, and various alteration-products probably replacing an iron-magnesia mica. One or two grains of another mineral are present, obviously much altered, which I cannot identify; possibly it may have been garnet.

E. *Crystalline Limestones.*

40. (E.N.E. of Tan y graig, Pentraeth, p. 213.) A finally granular clear rock consisting almost wholly of calcite or dolomite. Judg-

ing from the structure and optical characters, I should infer the presence of a considerable quantity of the latter mineral, and so name the rock a dolomite.

51. (E. of Bodwrog, p. 218.) Is more coarsely crystalline with an admixture of quartz grains and some silicate, which I am unable to identify with certainty; the carbonate, however, appears to be mainly calcite.

41. (At "a" of "Pentraeth," p. 213.) To the unaided eye appears less crystalline and less pure, resembling some limestones which have an admixture of volcanic mud. Under the microscope the calcite appears in rather irregular grains of fair size and rather brecciated aspect, imbedded in a streaky-looking paste composed of a pale green serpentinous mineral, of black and dark brown dust, with a little quartz, and of a clear silicate in minute granules, probably some kind of zeolite.

52. (Tau isa, N.E. of Cemmaes, p. 224.) Is moderately clear, chiefly composed of very minute granules of crystalline calcite and possibly dolomite, with occasional brown stains, and veined irregularly with more coarsely crystalline calcite. In no one specimen can I detect any distinct trace of an organism; but the first two rocks differ much from the last two, which might readily pass for members of the Carboniferous Limestone series.

F. *Igneous Rocks.*

39. (Fragment in green shale, E. of Bodorgan station, p. 214.) The ground-mass is thickly crowded with small and not very sharply defined felspar crystals, which, in their elongated form and the twinning of larger specimens, generally resemble members of the plagioclase group, interspersed with numerous minute grains of a pale green colour, of which the larger are distinctly dichroic and are probably hornblende. Small grains and occasional rod-like microliths of an iron peroxide are also present. Scattered about in the ground-mass are roundish patches of tessellated aspect, chiefly composed of crystalline quartz; one, in which the crystals are larger and by their enclosures indicate lines of growth, has calcite at the centre; this, however, as in the case of a neighbouring vein, is probably a subsequent infiltration. The majority more resemble imperfectly formed spherulites; a portion of the slide shows a distinct fluidal structure, and the ground-mass has a general resemblance to several modern lavas, *e. g.* to specimens in my collection from Astroni and the Solfatara (Phlegræan Fields).

53. (Carreg-winllan, Pensarn, S.E. of Amlwch, p. 222.) Exhibits a rather clear base, in which numerous small roundish patches are defined by exceedingly minute opacite and ferrite, the latter sometimes forming the inner edge of the boundary; it is also more or less powdered about through the base. With crossing Nicols this last is seen to be crowded with rather acicular felspar microliths, and the majority of the patches are well-defined spherulites with the usual radial structure. The rock is undoubtedly a trachyte, like the other; and, I think it highly probable that each is from a lava-flow.

Considering the locality and the consequent age of these specimens, their structure is most interesting. So far as my experience goes, there is nothing in either which would have awakened my suspicions as to their age, had they been labelled as from some locality where Tertiary or even more recent trachytes are found.

EXPLANATION OF PLATE VIII.

Fig. 1. Map of Anglesey, showing the distribution of the Palæozoic, Pebidian, and Gneissic series.
2. Generalized section from Holyhead Mountain to Menai Straits.
3. Section across Mynydd Llwydiarth.
4. Section from Porth Nobla to Aberffraw.
5. Section in Upper Quarry, Nebo.
6. Section in Lower Quarry, Nebo.

In all the sections the signification of the letters is as follows:—

d. Carboniferous.
c. Cambrian.
b. Pebidian.
a. Gneissic series:
a_6. Granitoidite.
a_5. Dark schist.
a_4. Grey gneiss.
a_3. Limestone.
a_2. Quartz schist.
a_1. Hälleflinta.
f. Faults.

Discussion.

Dr. Hicks agreed with Dr. Callaway that there are two Precambrian series in Anglesey. He differed from the author, however, in regarding the so-called granitoidite as constituting the lowest and not the highest member of the so-called Gneiss series. He stated that some of the breccias associated with the hälleflintas contain pebbles of the granitoid rocks, and are therefore of younger age than the latter. He admitted, however, that some of the points must be regarded as in an unsettled state, owing to the faulted condition of the district.

Prof. Ramsay argued against the principle of identifying rocks as of different ages by their mineral characters as studied by the microscope. He maintained that the altered rocks of Anglesey are the metamorphosed representatives of the Cambrian, because the unaltered Cambrian are found striking directly towards the altered strata, and both are overlain by the Arenig.

Mr. W. W. Smyth also argued against the recognition of a number of different formations on mineral evidence alone without any aid from organic remains. He thought the so-called "gneissose rocks" differ widely from typical gneisses, and that the granitic series belonged to the class of ill-defined granite rocks known in Cornwall as "bastard granite," the plain Saxon of which was perhaps preferable to the cacophony of "granitoidite." He thought that the evidence brought forward was insufficient to upset the detailed map of the Survey.

Prof. Bonney was inclined to agree with Dr. Callaway's interpretation rather than that of Dr. Hicks, as the latter undervalued the amount of metamorphism the Anglesey rocks by the Menai Straits had undergone. He differed from Prof. Ramsay as to the value to be attached to the microscopic study of rocks; he did not regard the Bangor rocks as partially metamorphosed, and he found no trace of the progressive metamorphism insisted on by Prof. Ramsay. He defended the use of the term "granitoidite," which, though open to objections, was less misleading than the base-born term proposed by Mr. Smyth. He thought that the microscopic study of the rocks supported Dr. Callaway's conclusions.

Dr. Callaway agreed with Prof. Ramsay as to the great value of the Survey work. He contended that the principle of the identification of rocks by their mineral characters is a safe one when applied in the same district. The sections described proved that the granitoidite was the summit of the gneissic series. Many of the gneissose rocks were true gneiss of very typical character. The difficulty through faulting was counteracted by comparing areas.

16. *The* LIMESTONE *of* DURNESS *and* ASSYNT. By C. CALLAWAY, Esq., M.A., D.Sc., F.G.S. (Read January 5, 1881.)

IT is well known that the late Sir R. I. Murchison based his determination of the Ordovician (Lower Silurian) age of the greater part of the Scottish highlands upon the discovery by Mr. C. Peach of Ordovician fossils in the Durness limestone. The views of Murchison were shared by many distinguished geologists, and have been generally accepted as one of the most assured and important conclusions of modern geological science. Wishing to ascertain for myself the truth of this opinion, I devoted a portion of last summer to the study of the limestone at Durness and Inchnadamff. I selected these localities because they alone are alleged to have yielded fossils from the limestone, and because Murchison regarded them as of primary importance in the construction of his argument. My researches led me to the conclusion, not only that the sections were broken, and therefore untrustworthy, but that the relations of the several rock-groups were inconsistent with the supposition that the limestone passed below any part of the newer metamorphic series. On my return from Sutherland, I found that many of my observations agreed very closely with those of Prof. Nicol; and I am glad to bear testimony to the accuracy of an author whose work has hardly received due recognition. It is certain that he made out many important points which escaped the observation of his distinguished rival; and I must, in candour, acknowledge that he has anticipated many of the results which I have now to submit to the Society. I can only claim to have ascertained some additional facts, which seem to me to strengthen the case against the received opinion.

DURNESS.

a. *The Limestone in Relation to the Flaggy Gneiss.*—In his later papers, Murchison admitted that the limestone was separated from the flaggy beds* by a "great fault," by which the "upper quartzite" was thrown down out of sight; but he, notwithstanding, held that the limestone was "overlain by the upper series of quartzose and gneissic rocks," apparently on the ground that both dipped in the same direction, to the east. Admitting his facts, his reasoning is obviously fallacious, and might be employed to prove the most opposite conclusions. But I cannot accept his facts. Neither the limestone nor the flaggy group dips to the east. The true relations of the two formations are shown in the annexed plan (fig. 1), which is, in outline, a reduced copy of the new ordnance map. The most important dips are shown by arrows.

* These flags are a true schist, though they are far less coarsely crystalline than the Lewisian.

Fig. 1.—*Sketch Map of the Durness Area.*
(Scale, about ¾ inch to 1 mile.)

The fault f_1 runs from sea to sea, east and west, exactly at the base of Far-out Head, which is entirely composed of thin-bedded gneiss and quartz-schist, dipping steadily to the north-east, except at some points a mile north of the fault, where the dip is consequently unimportant.

West of the ruined church, where the limestone contains numerous fossils, the dip is north-east, so that it might seem as if it passed beneath the schist. But here the nearest exposure of the latter is over half a mile to the north-east, the intervening area being occupied by blown sand, so that no junction can be seen. Further examination proves that this dip of the limestone is exceptional.

Following the strike of the schist to the south-east, we trace it right up to the fault. Both rocks are here clearly exposed, the flags on the shore and in the adjoining field, and the limestone in a low cliff, which is an inland extension to the west of the precipice of Creag Chearbach. The fault runs along the base of the cliff. The flags dip uniformly to the north-east, the nearest section being only twenty yards from the limestone, which, at this point, dips east-south-east. Several dips taken in this locality were the same, others veered round to the east, but none to the north of east.

Following the cliff along to the west, and noting the prevalence of south-easterly dips, we come, at about two furlongs east of Bailenacille, to a small arch of limestone, with dips ranging from south-east to north-east. Such local variations are obviously unimportant. In the area south of the fault the dips are almost uniformly to the south-east, as may be seen at many points between the inn and Sangomor.

Coming back to the west of the old church at Bailenacille, we find the north-east dip soon changes to east, and then to east-south-east, and on the Kyle of Durness the limestone forms an escarpment over a mile long, striking south-south-west and dipping clearly to the east-south-east. At many other points in the area round Durness the same dip is seen.

It is then certain that the mass of limestone lying south of the flags, and in immediate contact with them, dips south of east, northerly dips being quite exceptional, and then occurring only at a distance from the schist. As the latter dips steadily to the north-east, it is difficult to see how it can be conformable to the limestone.

But a more comprehensive view of the district presents the received view in a still more incredible light. East of Sango Bay is the Smoo mass of limestone. Though separated from the Durness area by a faulted strip of gneiss, it preserves the same south-south-west strike. East of Sangomor it steadily dips east-south-east, at Smoo it is about horizontal, but west of Sangobeag it turns up to the south-east and a syncline is formed. On the promontory of Leirinmohr some of the dips are nearer south than east; but in no case have I observed in the Smoo mass the north-easterly dip of the altered series.

As Murchison himself admits that higher up the valley the limestone is faulted against the old gneiss on both sides, it is needless to follow it further.

b. *Gneiss of Sango Bay.*—Between the two limestone areas is a band of schist. On the shore it is well exposed, not "thrust about in dire confusion," but forming a symmetrical half-dome facing to the north-east. On the east side, within a few yards of the limestone, and dipping towards it obliquely (that is, to east-north-east, at 40°), is hornblendic and chloritic gneiss. Towards the west the dip curves gradually round to north-east and north, and the gneiss is then underlain by dark mica-schist, which soon occupies the shore, the dip turning round to north-north-west, and finally to north-west, as if it would pass beneath the limestone which crops up in the shore close at hand, and is seen in the cliffs with its usual low south-easterly dip. There is no doubt that this strip is faulted (f_2 and f_3) against the limestone on both sides.

This gneiss is of the same kind as that which underlies the flaggy schist on Far-out Head and east of Loch Erriboll, and it must not be confounded with the Lewisian, which in this district is very massive, coarsely crystalline, and almost vertical in its dip. According to received views, this newer gneiss must overlie the limestone; and, if so, the force which contorted the former must also have affected the latter. But though the limestone comes up to the gneiss on both sides, its gentle south-east dip is not changed. It would appear to be more reasonable to infer that the limestone was deposited on the contorted gneiss, and that the latter was subsequently thrust up through the former between two parallel faults.

c. *The Quartzite.*—The bay between the limestone promontory of Leirinmohr on the west and the headland of Lewisian gneiss on the east is occupied by the quartzite, which is also seen sloping down from the flanks of Ben Keannabin to the bay and forms a small outlier on the headland just named. It dips uniformly to the north-east. In the western angle of the bay it is faulted (f_4) against the limestone. Both limestone and quartzite are crushed into thick breccias at the junction, and on the bank immediately above the limestone is seen dipping to the north-west, the strikes of the two formations being, as in the former case, nearly at right angles.

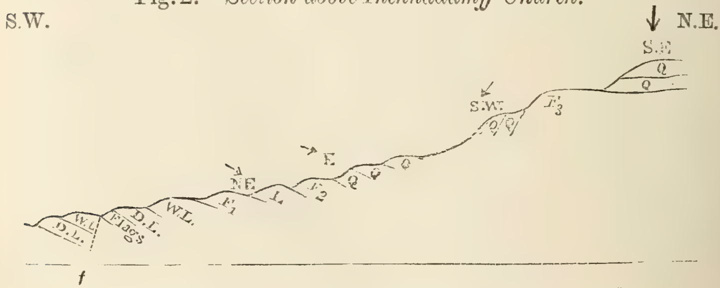
To sum up these results, it is clear that the metamorphic rocks, quartzite and schist, have been affected by a force tilting them up to the north-east, while the limestone forms a syncline whose axis strikes to the south-south-west. How the limestone can hold a conformable relation to the altered groups is a problem which the advocates of the received view may fairly be called upon to solve.

Though the metamorphic rocks occur in three distinct patches, it is probable that they form a true succession. To the east of Loch Eirriboll, the quartzite is overlain by gneiss of the Sango-Bay type, which is surmounted by the flaggy group on Loch Hope. In Durness the Sango-Bay gneiss must overlie the quartzite, since the latter rests on the Lewisian gneiss; and if the flags of Far-out Head were prolonged on the strike to the south-east, they would overlie the newer gneiss.

Assynt.

The section on which Murchison placed chief reliance is the succession on the south-west slope of Cnoc an drein, above the church. As I entirely differ in my reading, I submit a section of the ground (fig. 2), in which I have carefully excluded hypothesis and have simply inserted the facts observed.

Fig. 2.—*Section above Inchnadamff Church.*



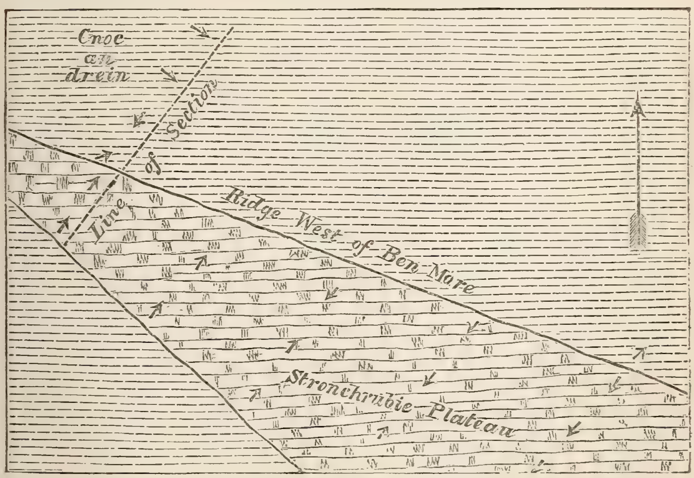
L. Limestone. DL. Dark Limestone. F. Felsite.
WL. White Limestone. Q. Quartzite. *f*. Fault.

Just above the road we come to a band of dark limestone, which is succeeded by a white zone. Beyond a little hollow, quartzose flags are followed by similar dark and white limestones, which are probably a repetition; then in succession we have felsite, limestone, and felsite. Hitherto the dip of the bedded rocks has been to the north-east. Above the felsite is a considerable thickness of quartzite dipping east, so that if it overlies the limestone it must be unconformable. Higher up the quartz-rock dips for some distance to the south-west. Approaching the summit of the hill, felsite appears, and just beyond is massive quartzite dipping steadily to the south-east for a considerable distance.

It is obviously unsafe to base a succession upon such a broken section as this. Passing over the intrusions, it is certain that more than one fault * occurs, and that the strike of the limestone is at right angles to the main mass of the quartzite. But a still more decisive refutation of Murchison's views remains.

Following the strike to the south-east it is seen gradually to recede from the quartzite ridge, while opposite dips by degrees come in on the northern side of the limestone band, which thus expands in the plateau of Stronchrubie into a broad syncline, the northern side of which *dips away* from the quartzite, that is, to the south-west. Towards the ridge the limestone dips grow steeper and at last approach the vertical. Climbing the face of the mountain above, the quartzite is seen to dip to the north of east, so that the dips of the two formations are in opposite directions. As the northern side of the syncline gradually disappears towards Cnoc an drein, it is obvious that it is cut out by a fault, so that the southern side of the basin is brought against the quartzite and appears to dip below it. These facts are illustrated in fig. 3.

Fig. 3.—*Plan of Limestone and Quartzite at Inchnadamff.*



* Almost certain at F_2 and F_3.

There is another difficulty in the reception of the old view. According to Murchison, the limestone is conformably overlain by the great mass of quartz-rock which rises into the lofty peaks of Ben More. If so, then the limestone basin of Stronchrubie must have been covered by an equal thickness of quartzite. It is for the followers of Murchison to show how denudation could have cleared off the entire mass of such an intractable rock as quartzite from the limestone, and yet have made so little impression upon the mountain-ridges which overhang.

The quartzite which slopes down from the south-eastern face of Queenaig passes up through a continuous quartzite ridge into Ben More. It is not pretended that the limestone occurs in this line of section; but it is very singular that it should have thinned out just where its presence would have been of decisive value.

One important and suggestive fact remains. At both Durness and Assynt the limestone forms a symmetrical basin, the axis of which does not agree with the normal strike of the rocks which are supposed to overlie, but which *coincides with the axis of the existing valley in which it lies.* In Assynt the axes strike to the south-east, at Durness to the south-south-west.

I do not at present press these conclusions beyond the districts observed, but submit them as an instalment towards the solution of a great question.

Discussion.

The President said he had twice visited the area, and felt difficulties in tracing the succession of the rocks, especially as to the asserted recurrence of the quartzites. The fossils proved the limestone to be of about Arenig age; certainly the limestones seemed to lie in a synclinal basin on the quartzites.

Prof. Judd said that, after several visits to the district, he felt great difficulty in offering an opinion as to the succession of beds; he thought the simple sections commonly drawn to illustrate the geology of the country did not hold good. He considered that Prof. Nicol had made good his position as to there being only one quartzite and one limestone; but as to the relation of these to the gneiss, there was great difficulty in arriving at a satisfactory conclusion.

Dr. Hicks agreed that the limestone series sometimes lay in synclinal folds of the quartzite; but he thought there might be two quartzites, as in a case he had recently noticed in another region along the same line further south. He was thoroughly satisfied that the series was newer than, and did not underlie, the eastern gneiss.

Mr. Hudleston observed that Dr. Callaway's mapping of the Durness area coincided with Sir R. Murchison's section as to the limestone being troughed, and also as to the reversed position of the two gneisses. Further south the quartzites and limestones appeared to be intercalated, as at Loch Erriboll, where *Orthoceras* had been obtained from the quartzite, tending to show that the two rocks hang together. The Assynt series, though less distinct than that at Loch Erriboll, was not inconsistent with such an idea. The unequal tension of the two rocks might in part account for local discordance of strike.

Dr. Callaway could not agree with Mr. Hudleston as to his interpretation of the Durness section; such discordant strikes were incompatible with the idea of a conformable succession; nor did he agree with his view of the Loch-Erriboll rock. He accepted the age of the limestone.

17. *On a* New Species *of* Trigonia *from the* Purbeck Beds *of the* Vale *of* Wardour. By R. Etheridge, Esq., F.R.S., Pres. G.S. *With a Note on the Strata*, by the Rev. W. R. Andrews, M.A. (Read December 15, 1880).

Early in this year the Rev. W. R. Andrews, of Teffont Rectory, near Salisbury, placed in my hands what at first sight appeared to be a new species of *Trigonia* from the Purbeck rocks in the Vale of Wardour. This new species was found by Mr. Andrews in the railway-cutting one mile west of Dinton Station in the Vale of Wardour; and its geological or stratigraphical horizon is the "Cinderbed" so well known in the several sections in the Isle of Purbeck and elsewhere. This bed is here composed of hard grey marl and pale brown soft limestones, variable in their proportions. *Ostrea distorta* and casts of *Trigonia* abound in this Cinderbed, which here measures about 2 ft. 6 in. in thickness. The section accompanying this paper (fig. 2, p. 252) was constructed by Mr. Andrews, and most correctly represents the succession of the Lower and Middle Purbecks at the spot in the vale whence the new *Trigonia* came. It was from this marine "Cinderbed" at Durlston Bay that *Hemicidaris purbeckensis*, Forbes, was obtained, associated with *Ostrea distorta*, a *Trigonia* like *T. gibbosa*, *Cardium Gibbsii*, *Perna* sp., and remains of fish. No other locality or section of the Dorsetshire Purbecks has yielded the above. There cannot be any doubt that this *Trigonia* is not *T. gibbosa*. The Rev. O. Fisher obtained *Trigonia gibbosa* (?) from the middle Cinderbed of Fovant, Wilts; and the Rev. Mr. Andrews has obtained four other specimens of the same species from his immediate area; so that the genus is well represented in the Middle Purbeck of the Vale of Wardour. The Lower Purbeck beds of the vale lie below the datum of the railway and the level at which many of the quarries are worked, the "Juxeat" beds being about the lowest seen. The beds exposed in the railway-section near Teffont include the base of the Wealden, *all* the Middle Purbecks of the Vale of Wardour, and the top of the Lower Purbecks. The middle group here is about the same thickness as the beds in the Isle of Purbeck; those at Ridgway Hill and Mewps Bay are about 50 ft.; and at Worborrow Bay the middle series measures 90 ft., and at Durlston Bay 150 ft. There is no Upper Purbeck in the area under observation; the hard marl with eroded surface is the highest member of the Middle Purbeck, the succeeding 17 ft. being probably Hastings Sand at the base of the Wealden.

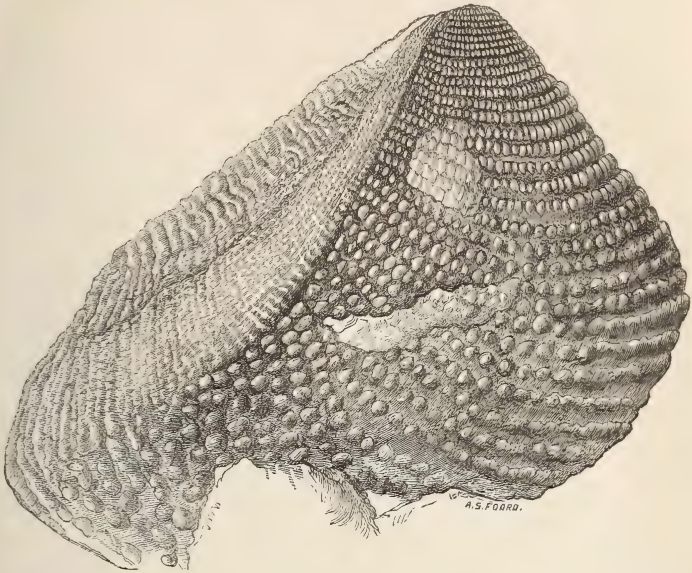
Description.

Section Glabræ.

Trigonia densinoda, Ether. (Fig. 1.)

Shell greatly elongated or lengthened posteally, the anteal or anterior side rounded and somewhat steep; the base (inferior or ventral border) flattened; the postero-dorsal (umbonal or superior) border concave and much elongated.

Fig. 1.—*Trigonia densinoda*, Ether.



Umbones pointed, small, but prominent or elevated and slightly recurved, antero-mesial, or placed within the anterior third of the valves.

Area moderately wide, flattened and filled with reticulated costellæ, which are minutely and delicately nodulated or tuberculated; it is bounded by two carinæ, the outer densely or closely nodulated, increasing in width from the umbo to near the extremity of the posteal side, then merging into the system of tuberculated transverse costæ; or the extreme posteal border possesses many irregular lines of growth due to the elongation of the tubercles. The inner carina, or that bordering the escutcheon, consists of a series of minute tubercles which are immediately surmounted by the tranverse wavy ridges of the escutcheon. The median sulcus, or mesial furrow, is well defined. The escutcheon is remarkably large, having transverse wavy rugæ resembling those occurring in the Neocomian Quadratæ. The shell (valve) possesses regularly and concentrically arranged tuberculated or knotted rows of costæ; about 40 range from the umbo to the posteal attenuated border. Those tubercles upon the posterior third of the valve, below the area become elongated and less regularly arranged than those of the umbonal region, where they are closely concentrically arranged.

Affinities and Differences.—In outward ornamentation *T. densinoda* mihi, much resembles *T. tenuitexta* from the Portland Oolite of Portland, Devizes, Crookwood and Tisbury; but the shell is more depressed and lengthened posteriorly than *T. tenuitexta*, and does not possess the antecarinal sulcus or space of that species, which occurs in all the known Jurassic Glabræ, and which is so essentially characteristic of the Portland group.

The ornamentation is that of the Upper-Jurassic Glabræ; but the escutcheon, which is remarkably large and possesses transverse rugæ, agrees with that of the Neocomian Quadratæ, to which it allies the species.

All the Neocomian Quadratæ have the escutcheon ornamented, and therefore distinct from that part of the tuberculated Jurassic species in which it is plain or unornamented. Again, the Cretaceous Scabræ have also ornamented escutcheons; but the latter are altogether different and far removed from the Jurassic *Trigoniæ*.

I therefore regard this new species of *Trigonia* as a transition form, tending to connect the Portlandian Glabræ, through its ornamentation, with the Neocomian Quadratæ, through the ornamented and peculiar or characteristic escutcheon. Its stratigraphical position at the highest portion of the Jurassic system indicates a zoological change in progress as regards the genus *Trigonia*, constituting an important feature in the history of the genus, no other example of which, so far as I am aware, is known in rocks representing the Purbeck formation, either British or continental.

This new species falls under the group or section Glabræ, founded by Agassiz upon very insufficient data, and described by him as being without ornamentation, having no tubercles or costæ. The shells of this group are usually "inflated-ovate or ovately-oblong; and the area is only slightly separated" from the rest of the valve.

Mesially, or anterior to the position of the marginal carina, there is a smooth space which commences at the apex (umbo) or near it, and gradually widens downwards to the posteal border. This smooth space is more depressed than any other portion of the valves, and is distinctly impressed by lines of growth.

In this group the "anteal" portion of the valves possesses costæ more or less prominent, usually small, closely arranged, and either plain or tuberculated. The number of species belonging to this section is seven, six of which are Jurassic, the remaining form being Cretaceous (*T. excentrica*, Park.).

Our species is closely allied to those forms known in the Portland rocks under the name *T. gibbosa*, Sow., *T. Damoniana*, de Lor., *T. Manselli*, Lycett, and *T. tenuitexta*, Lycett, and especially to the last named, from which, however, it differs in form and characters.

NOTE *on the* STRATA. By the Rev. W. R. ANDREWS, M.A.

Mr. Andrews has drawn up the following description of the Purbeck beds of the Vale of Wardour; and any of the sections would suffice to read aright the succession and position of the fossil under consideration.

Mr. Andrews says, "the Purbeck strata occupy an area of from five to six miles square at Teffont Ewias, Chicksgrove, Lady Down, &c. in the centre of the Vale of Wardour, and rest conformably upon the Portland group, sometimes, but not always, separated by a thin band of dark clay. These estuarine deposits have been considered to belong to the Jurassic system, in consequence of their presenting remains of animal life nearer in affinity with the Jurassic period than with the Wealden above, and also from the fact that the marine Portland beds pass into the freshwater Purbecks without unconformity, and generally with an ancient land surface at or near the junction ; the same area too (for the Portland beds are always capped by the Purbecks) which formed the bottom of the Portland sea, became when raised, first the support of the ancient forest, and then, when again slightly depressed, the delta of some great river, and this without any unconformity or denudation, which would imply a great lapse of time.

"The Purbeck beds in the Vale of Wardour are comparatively much thinner than those exposed on the Dorsetshire coast, and here present only about 60 or 70 feet, belonging entirely to the lower and middle divisions.

"Whether the Upper Purbecks were ever deposited here, it is impossible to say. These Purbeck beds thin out rapidly on the coast, passing from E. to W., or from Durlston Bay to Portland Bill, and also from S. to N., passing from the same exposure at Swanage through the Vale of Wardour to the thin capping at Swindon. This thinning-out may have been due to the north and west sides of the estuary being raised and above water when the Upper Purbecks were being deposited in the south and east—a supposition which is borne out by the Purbeck at Swindon, shown by Mr. Blake to be 'in point of time as old as some parts of the Portland.' Or, on the other hand, the upper beds may have been deposited and denuded—a supposition not improbable when we remember that the Cretaceous system rests quite unconformably on these freshwater beds, *e. g.* the Gault in the Vale of Wardour overlapping the beds below.

"New quarries, opened since Fitton wrote his memorable paper, have supplied some very interesting fossils, amongst which is the new *Trigonia* (*T. densinoda*).

"At the junction of the Purbeck beds with the Portland strata there generally occurs a thin bed of dark clay; and some few feet above may be seen an ancient earth or land surface, which is, in places, as much as 2 feet thick. This bed has in it large pieces of coniferous wood and a Cycad, as in the Isles of Portland and Purbeck. The "cap" as it called, is here visible, and has yielded some interesting Mollusca, besides several species of fishes, and a very much larger form of *Archæoniscus* than *A. Brodiei.* The beds immediately above the Middle Purbecks are not well exposed, they consist (as on the coast) of soft shales with Cyprids and marls, affording no good stone worth the quarryman's labour. These, I presume, would be equivalent to the soft cockle-beds of the Durlston section.

"At the top of the Lower Purbecks and in the Middle Purbecks much useful stone occurs, and has been extensively quarried both for building-purposes and for burning into superior lime; from these exposures some interesting fossils have been obtained.

"Thick beds of a hard grey marl at the top of the Purbecks, very similar in appearance to the insect-beds of Durlston, but containing *Cyprides*, here afforded some few insect-remains, several species (6) of fishes, and *Archæoniscus* (the fishes are the following—

Microdon radiatus, *Ophiopsis breviceps*);
Pleuropholis,

also Turtle and Crocodile remains. The insect-remains are not so plentiful as at Durlston, a comparative scarcity arising from the terrestrial condition of these beds in the Vale of Wardour, as evidenced by the presence of *Cyprides*.

"Passing up through the "cherty freshwater" beds, which here contain, as in Dorsetshire, *Paludinæ* and *Cyclades* beautifully imbedded in flint, we arrive at one of the most interesting beds of the whole series, a marine bed called, in the island, the "Cinder." Although it is much reduced in thickness from 12 ft., crowded with *Ostrea distorta*, still, in the Vale of Wardour, it maintains its marine character, and, as elsewhere, from its hard enduring nature, has outlasted many softer beds. Beside the *Ostrea distorta* which is scattered through it, two species of *Trigonia* occur, *T. gibbosa* and a new species which Mr. Etheridge has named *T. densinoda*, which has not occurred in any other formation and, according to Mr. Etheridge, is of much palæontological interest, arising from the fact that it has characters connecting it with the Jurassic *Trigonia*-group Glabræ, on the one hand, and Cretaceous forms of the group Quadratæ, on the other. Occurring, as it does, in beds of a transitional character between the Jurassic and Cretaceous, it is more interesting still.

"Higher up in the Middle Purbecks occurs an extraordinary abundance of the fossil Isopod *Archæoniscus Brodiei*, sometimes so closely lying together that 250 specimens have been obtained on a slab not larger than one foot square. The 8 or 10 feet of red and yellow stratified sandy clays which are here found on the top of the Purbecks, are possibly the Wealden. They rest upon an eroded surface of limestone, but otherwise present no unconformity. It is remarkable that these Wealden beds so often cap the Purbeck series, a fact that seems to indicate that the same area which served for the delta of the Purbecks performed the same office for the Hastings series, with, however, this difference—that the source from which the materials came must have been different, although the ancient river may have served for both formations.

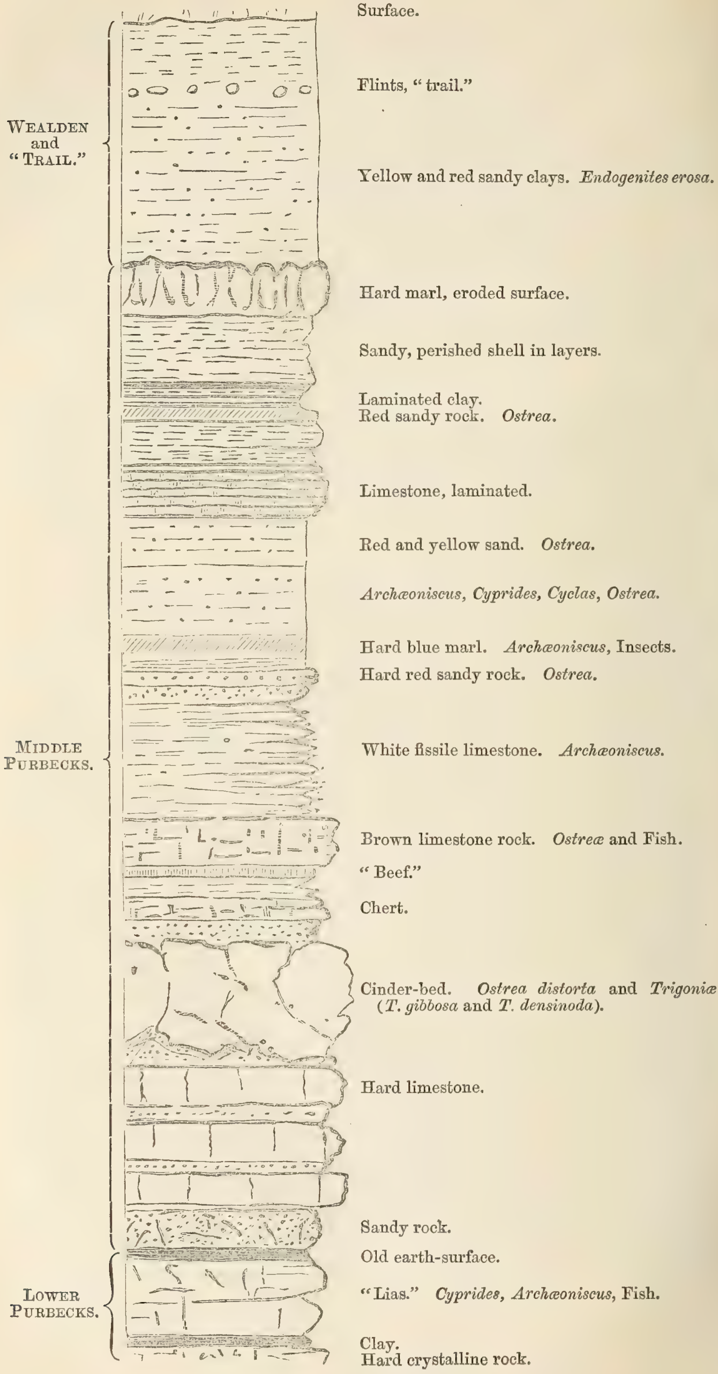
"*Endogenites erosa*, not hitherto clearly proved to belong to any other horizon than the Wealden, has been found in these red and yellow sandy clays *in situ*; a stratified bed above contains a small *Modiola* and *Cyrena*; but whether Wealden or Purbeck, I am not able to say. *Endogenites erosa* occurs in a similar section half a mile to the east."

The Rev. Mr. Andrews has made a careful section of the railway-cutting at Teffont, which shows the Hastings beds and the Middle and Lower Purbecks. The Rev. O. Fisher marked the divisions on the section. Mr. Andrews is of opinion that no higher Purbeck beds occur in his neighbourhood than those shown on the section, and that the Hastings series were deposited upon the eroded Purbeck strata; the Purbeck strata continue 50 ft. or more below the base of the railway-cutting, as there are many quarries in the neighbourhood with many feet of Purbecks resting upon the Portland beds. The section in the railway-cutting ends 7 ft. below the "cinder bed;" but the quarry near the Rectory has been carried 19 ft. below the "cinder," into hard grey marls, which are burnt for lime, and contain many fish, insects, *Archæoniscus*, *Cyclades*, *Cyprides*, &c.

The following is a detailed section of the Portland beds in the railway-cutting, drawn up by Mr. Andrews, which, although similar to the woodcut-section on p. 252, nevertheless enters more into the particulars of the beds, both as to thickness and succession, and will doubtless be found useful if the district is visited and examined: —

	No.	ft.	in.	Surface.
Hastings Beds.	1.	2	0	Brown earth, with scattered flints, passing into
	2.	2	0	Red and yellow sand, with a few scattered flints.
	3.	1	6	Grey sand with red streaks, passing into
	4.	1	0	Grey sandy clay, red and yellow layers.
	5.	0	2	Purplish red clay, laminated.
	6.	0	6	Green clay, light-red lines.
	7.		½	Layer of iron in laminæ.
	8.		1	Green clay, red irony lines of variable thickness, resting unconformably on the bed below, and running down amongst the lumps.
Middle Purbecks. *Corbula*-beds.	9.	1	0	Worn flint-shaped lumps of hard marl, vertical fracture.
	10.	1	6	Sandy, with perished shells in layers.
	11.	0	6	Clay, red and grey, in laminæ.
	12.	0	2	Very red sandy rock, sometimes blue and grey, with large bivalves, *Ostreæ*.
	13.	1	0	Limestone layers in sandy clay.
	14.	0	9	Thin laminated brown sandy limestone.
	15.	1	0	Hard sandy stone, often red outside, ripple-marks on the top.
	16.	1	0	Composed of perished shells, thin layers of limestone and a line of "beef" about the middle.
	17.	1	4	Red and yellow sand in layers. *Ostreæ*.
	18.			Clay, thin-laminated, soft and yellow; impressions of *Archæoniscus*.
	19.	0	9	Hard blue and brown marl, *Archæoniscus*, *Cyprides*, *Cyclas*, *Ostreæ*, insects' wings.
	20.	0	3	Laminated thin white limestone and sand.
	21.	0	3	Hard red sand rock, occasional streaks of blue; oysters and impressions of large bivalves.
	22.	0	2	Soft sandy limestone.
Carried forward		16	11½	

Fig. 2.—*Section of Purbeck-Beds in a Railway-cutting* $1\frac{1}{4}$ *mile west of Dinton Station, Vale of Wardour.* (Scale, $\frac{1}{4}$ inch to 1 foot.)



Group	Sub-group	No.	ft.	in.	
		Brought forward	16	11½	
Middle Purbecks (*continued*).		23.	1	4	Soft white limestone, laminated, "White bed." *Archæoniscus.*
		24.	1	0	Brown rock, shelly, large bivalves, oysters, fish-remains.
		25.			Oolitic stone, brown.
		26.			Soft limestone, vertical fracture.
	Chert Beds, "Cinder."	27.	0	2	"Beef."
		28.	0	6	Sand and limestone in layers.
		29.	0	2	Chert.
		30.	0	2	Sandy clay, dark brown, shelly.
		31.	2	5	Hard grey marl, and brown soft rock, very varying in their proportions, sometimes the hard marl taking up all the space, and *vice versâ.* "Cinder" containing scattered *Ostrea distorta,* and *Trigoniæ.*
		32.	3	0	Hard crystalline limestone, in 1, 2, or 3 layers, with thin sand or clay between, blue outside, and containing lumps of chert, *Cyclades* in clay parting with vegetable remains and *Paludinæ. Cyclades* and *Ostreæ* in the chert.
		33.	1	0	Sandy rock, yellow.
Lower Purbecks.		34.	0	2	Dark clay.
		35.	1	6	Hard grey marl. Insect-beds of Purbeck.
		36.	0	2	Clay.
		37.			Hard crystalline rock, shelly.
			28	6½	

Discussion.

Mr. Hulke remarked that the fauna of the "Cinder-bed" being very limited, even where it was best known, namely at Swanage, any addition to it was of great importance. The discovery of the species described by Mr. Etheridge was especially important, the fossil being so strongly characterized that no doubt could be entertained as to its distinctness, while, at the same time, it was particularly interesting as binding together two other forms, an older and a younger one, and thus, to a certain extent, bridging over the gap between the Jurassic and Cretaceous *Trigoniæ.*

Dr. Duncan thought that the Wealden-Purbeck forms a series intermediate between the Cretaceous and the Jurassic.

Prof. Seeley agreed with the author that the form is a new species.

The Author stated that he had shown the specimen to Dr. Lycett, who agreed with him as to its peculiarities of character.

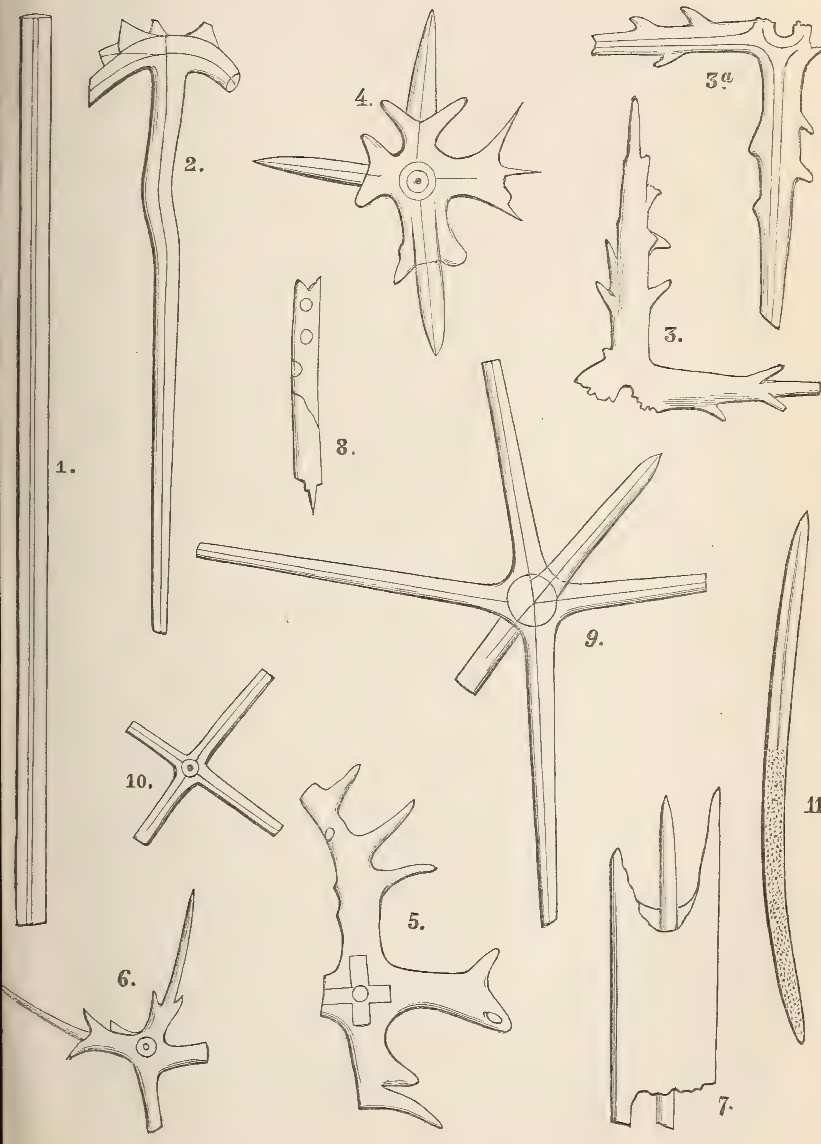
18. *On* ASTROCONIA GRANTI, *a new* LYSSAKINE HEXACTINELLID *from the* SILURIAN FORMATION *of* CANADA. By W. J. SOLLAS, Esq., M.A., F.R.S.E., F.G.S., Professor of Geology in University College, Bristol. (Read February 23, 1881.)

BY the great kindness of Lieut.-Col. Charles Coote Grant, I have received a valuable collection of fossil specimens from the Silurian strata of Hamilton, Ontario. I hope, as opportunity serves, to offer descriptions of the more interesting of these fossils, and in the following short paper make a beginning by describing an incompletely silicified specimen of chert, which by its remarkable similarity to the chalk-flints of Trimmingham arrested my attention when studying those bodies. The specimen in question is a small piece (1 inch cube) of greyish siliceous dolomite with a gritty granular texture; on one face it bears a carbonized Hydrozoon, on another a silicified Polyzoon, and on a third shows the opening of a long winding cavity which extends into the interior. From the sides of this cavity some long cylindrical rods, very suggestive of sponge-spicules, were seen conspicuously projecting: under the microscope by reflected light they were seen to be covered with an irregular crystalline deposit, which made the resemblance to spicules less striking than when examined by the unassisted eye. The specimen was now broken into two pieces, and the part containing the rods and cavity placed in dilute hydrochloric acid. Solution with faint effervescence took place; and after standing for twenty-four hours the supernatant liquor was poured off for subsquent examination, while the sediment and small piece of siliceous dolomite remaining were well washed and further examined. From the sides of the cavity in the dolomitic chert, cylindrical rods were still seen projecting, and under the microscope were found to have lost their irregular outline and at the same time to have somewhat diminished in thickness; evidently a crystalline coating had been dissolved away from them; and in the slender siliceous rods which remained one recognized at once true sponge-spicules.

The sediment was next examined. It contained a number of large siliceous spicules, some of which are figured on page 255, also some small colourless transparent hexagonal prisms capped with six-sided pyramids at each end, evidently quartz crystals, and, finally, some minute rhombohedra, which were subsequently found to be magnesite.

The Sponge-Spicules.—By reflected light the spicules appear snow-white, with a vitreous lustre; by transmitted light they are glassy and translucent; when immersed in water, glycerine-jelly, or Canada-balsam, they become quite transparent, except in places where they are traversed by a minute black spongy network which appears white and shining with reflected light, and evidently contains air: when this is displaced by the liquid medium, the spicule becomes

Figs. 1–11.—*Spicules of* Astroconia Granti, *Sollas.* (All magnified 40 diameters, except figs. 3, 5, and 7, which are magnified 104 diameters.)



transparent throughout; it is frequently colourless, but sometimes presents a faint yellowish brown tint either in places or throughout. The surface of the spicule has a rough irregular appearance when examined dry, which disappears, however, on immersion in balsam, being evidently due to a crystalline incrustation (magnesite). When this is removed the sides of the spicules appear as neat continuous lines; the axial canal is also quite sharply defined, and is sometimes not more enlarged than in recent deciduous spicules, though occasionally it is so wide as to reduce the spicule to a mere shell. In some instances it has been infilled with silica, so as to appear as a cylindrical rod projecting from what remains of the spicule in which it was formed (fig. 8, p. 255).

The spicules are not excavated by rhombohedral pits like those seen in *Hyalostelia Smithi*, Young, from the Carboniferous Limestone of Scotland; but sometimes they are pitted all over with hemispherical cavities such as are seen in deciduous and fossil spicules, and which can be produced artificially in recent spicules by solvent agents.

With polarized light all the spicules give brilliant colours, and much more vividly than those from the chalk of Trimmingham; the colours frequently occur in spherical patches, as though crystallization had been set up about various centres within the spicular substance; one might term it an internal botryoidal structure, though the spicules are never botryoidal externally; somtimes the polarization-effects show clearly that the spicule is composed of minute prisms radiating outwards from the sides of the axial canal.

In concluding this brief account of the mineral state of the spicules, I may remark that, though highly crystalline, they are almost if not quite as well preserved as those of *Hyalostelia* from the Carboniferous formation; and this is certainly surprising when we consider their greater age and much smaller size. The conditions under which the two sets of spicules were preserved were evidently very different, however; for *Hyalostelia* does not appear to occur in association with deposits of chert as is the case with *Astroconia*. *Hyalostelia* is possibly preserved to us chiefly by reason of the magnitude of its spicules, *Astroconia* chiefly by secondary silicification.

We now pass on to a description of the forms of the several spicules, which are figured on page 255, all being magnified 40 diameters except figs. 3, 5, and 7, which are magnified 104 times.

Fig. 1 is the commonest form, occurring in fragments of various lengths, that represented being the longest seen. It is almost exactly cylindrical; and the axial canal maintains a straight course and even width throughout. Its natural termination has not been seen; but probably it was pointed at both ends, and formed the acerate spicule of the sponge.

Fig. 2 looks at first sight like the trifid spicule of a Tetractinellid; but careful examination shows the presence of four rays, of which that marked *a* is one; though as here represented it appears merely as a bifurcation of the one in front of it. By examining the other side of the glass slide on which the spicule is mounted its real nature is readily made out; moreover I was able to turn an almost exactly similar spicule over on its head, so that its shaft projected vertically; the four capitular rays could then all be seen in one view. The axial canal of the shaft is prolonged upwards past the common origin in the head, and, no doubt, once extended into a short vertical spicule; indeed the companion spicule shows as much. In addition to this axial spine, containing a continuation of the canal, the head is ornamented by conical tubercles given off in the same direction from the upper surface of the capitular rays (as shown in the figure).

I take this spicule to have projected radially from the surface of the sponge-body, the shaft being directed inwards and the capitular rays expanding parallel to the surface of the body, as in the similar spicules of *Holtenia* and *Rossella*; it has not the appearance of an anchoring spicule.

Figs. 3 and 3*a*. These two drawings represent the same specimen, the upper one taken before immersion in a liquid medium and by reflected light, the lower one by transmitted light when mounted in Canada balsam. They are magnified 104 diameters: so that, if represented on the same scale as the other figures, they would not be quite so large as the spicule represented in fig. 6. The noticeable feature is the presence of spines on the rays, directed in all cases towards the ends. The rays were evidently at least five in number; probably there were six.

Fig. 4. The four rays of this spicule are directed downwards below the plane of the paper; near their origin they each give rise to a large bifid spine inclined upwards away from the plane of the paper. It is probable that this specimen once formed the head of a spicule like fig. 2.

Fig. 5. This spicule ($\times$ 104) is chiefly remarkable for its spinose rays: on the longest but still broken ray three spines are given off from one side, and a fourth, represented in plan by a circle, from the adjacent side at right angles.

Fig. 6. The proximal half of the rays is thicker than the distal end, which is long, slender, and directed downwards, the proximal half lying in the plane of the paper. The thicker part of the rays is spined—the spines (so far as one can judge from the three which remain on one of the rays) being arranged spirally, and two of them arising near the origin of the slender extremity.

Fig. 7. This represents a fragment of a cylindrical spicule magnified 104 diameters, with the axial canal filled up with silica, which now projects at both ends like an acerate spicule run through the middle.

Fig. 8 is also a fragment of a cylindrical spicule; it shows the hemispherical pits which have been eaten out of its surface.

Fig. 9. This is one of the most frequently occurring forms; it is a large simple sexradiate—the rays having a cylindrical form, only slightly tapering towards their broken extremities. The axial canals are regular and clearly defined. This is probably one of the staple body-spicules of the sponge.

Fig. 10 is a smaller spicule of the same kind.

Fig. 11. This is less like a Hexactinellid spicule than the others,

possibly owing to its being incomplete and yet simulating completeness through a sharpening of its ends by solution. The axial canal can be clearly traced through one half of it only, the other half being rendered opaque by the close firm network of cavities which excavate it.

Leaving out of consideration the last, which is a doubtful form, and a few other fragments not figured and quite undeterminable, one may safely say that all the spicules extracted from the small fragment of dolomitic chert are distinctly Hexactinellid; and it would appear that we probably have here, not a heterogeneous mixture of spicules derived from several kinds of sponge, as is usually the case in chalk-flints, but the much rarer case of a natural assemblage of forms derived from a single individual. For this group of forms we propose a distinct name, *Astroconia Granti*, the specific designation being given in honour of the indefatigable observer to whom we are indebted for our knowledge of the sponge.

The Quartz Crystals.—These do not differ in character from those described from the Carboniferous Limestone by Mr. Wardle and in my papers on *Catagma* (Ann. & Mag. Nat. Hist. ser. 5, vol. ii. p. 361, fig. 3), and on Flints (vol. vi. p. 445). I have also called attention to the important part which such such crystals play in rock-formation by pointing out that certain beds of sandstone in the Eden valley appear to partly consist of them. If we knew the bulk of these beds, we might calculate the amount of limestone which must have been denuded to produce them, on the assumption that this limestone contained 1 oz. of crystals in every 10 lb. of rock, as is the case with that at Buxton at the present day. I believe that in these quartz crystals, derived undoubtedly from siliceous organisms, we have also the key to the origin of the "krystallinische Quarzpsammite" of Naumann, which occur in several formations on the continent (Zirkel, Lehrbuch der Petrologie, vol. ii. p. 575). They are nothing but the insoluble residues of limestone masses which have been dissolved away by the action of subaerial waters*. If this be so, we have in these crystalline sandstones the last stage of one of those beautiful cycles or, rather, spirals which appear to characterize the operations of nature: the silica derived from the disintegration of igneous rocks is carried in solution into the ocean and there built up by living organisms into forms of endless diversity and exquisite beauty; this organic silica again yields to solvent influences and afterwards crystallizes out amidst calcareous sediments in perfectly formed crystals of mineral quartz; the calcareous rocks elevated above the sea-level are exposed to water and the weather; solution proceeds apace; and after the carbonate of lime has become dissolved away, the

* This statement is too absolute. The beautiful observations of Mr. J. A. Phillips, F.G.S., in complete accordance with those of Prof. Bonney and Dr. Sorby, show that crystalline quartz-sandstones are sometimes formed in a quite different manner—indeed, that the formation of quartz crystals has been subsequent to that of the sandstone as a whole. In deciding upon the origin of such sandstones, we shall have probably to be guided by the circumstances in each case, before we can say certainly that the constituent quartz crystals are original or superinduced formations.

minute quartz crystals, uninjured and unworn, are washed into the sea to constitute afresh the mineral sediments of the earth's crust.

Rhombohedra of Magnesite.—These were left on the solution of the limestones in dilute hydrochloric acid, the majority of them occurring in a free and separate state, but a few imbedded in small fragments of chert, just like those figured by Professor Renard in his memoir on the 'Phthanites du Calcaire Carbonifère de Belgique' (Bull. de l'Acad. Roy. de Belgique, 2^{me} sér. t. xlvi. p. 471, 1878). To determine their nature, as well as that of the rest of the limestone, I made a preliminary qualitative analysis, first of the solution produced by the action of hydrochloric acid, and next of the undissolved residue. The former contained lime and magnesia, carbonate of lime and phosphate of magnesia being precipitated in apparently equal bulk; the residue was boiled with strong hydrochloric acid, and the resulting solution analyzed; it contained a little iron, not a trace of lime, but a considerable quantity of magnesia; hence one might conclude that that part of the rock which is not chert, is dolomite, while its included rhombohedra, which were set free on solution, are magnesite; and a quantitative analysis is scarcely necessary.

The Geological Horizon.—The rock specimen was obtained from the chert beds of the Niagara Limestone, which is homotaxial with our Wenlock Limestone. It affords the oldest known instance of the associated occurrence of siliceous sponge-remains and chert. On the one side of a fragment of rock we find free spicules still siliceous, together with quartz-crystals imbedded in dolomite—on the other a mass of chert, in which spicules are rarely seen, and then usually as hollow casts, but which contains remains once calcareous (such as the Polyzoon before mentioned) now converted into silex.

Discussion.

The President said this was the oldest sponge next to *Protospongia*. The author's remarks on it were most valuable, and those on the collateral subject very interesting. It was to be hoped that Mr. Maw would discover in the English Wenlock Limestone some similar microscopic forms.

Prof. Duncan said it was interesting to see the modern Hexactinellids thus foreshadowed. Very lately he had seen one of the spicular forms described by Prof. Sollas in a form he had just described. He quite agreed with the author in assigning this form to the Lyssakine Hexactinellids. There could be no question as to the solution of the spicules in sea-water, as he had lately seen evidence of it in specimens from deep-sea dredgings. The results of Mr. Maw's washing promised to be very interesting. He had examined many, but had not yet found either sponge-spicules or Foraminifera.

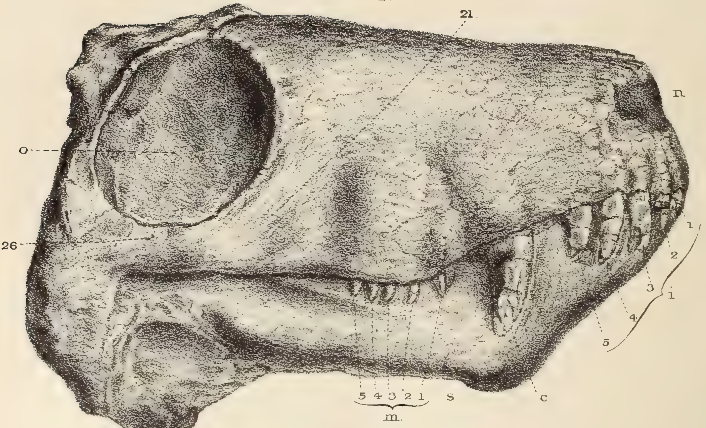
Prof. Rupert Jones remarked that there are different kinds of "chert," and expressed his opinion that Mr. Sollas had well explained the origin and formation of the spicular strata which he had described on this and other occasions. He thought that Dr. Wallich's hypothesis of the conversion of extensive layers of sponge-protoplasm into black flint elucidated many, but not all, of the phenomena connected with the origin of such siliceous strata as flint and chert. He stated that sponge-spicules, and numerous other Microzoa from the Upper Silurian shales of Shropshire, had been noticed lately by Mr. Smith of Kilwinning.

Dr. Hicks said that it was remarkable that chert was not associated with *Protospongia*, as, on either Dr. Wallich's or Prof. Sollas's view, might have been expected.

Prof. Judd said that, as the solution of siliceous organisms had been recently doubted, Prof. Sollas's observations were of additional interest. He himself fully believed that this solution did take place; now and then he had found, in examining the residues left by dissolving chalk in acid, the thickest portions of siliceous spicules still remaining not quite destroyed in chalk.

Prof. Sollas replied that he believed a spicule had been described by Mr. Carter similar to that mentioned by Prof. Duncan. The one described now by him, however, was much more robust. He had never been able to find spicules in the Wenlock. He could not comprehend what Dr. Wallich's views really were. That none of the fossil siliceous spicules which the author had described were originally calcareous was quite certain. As for *Protospongia*, it did not occur in limestone, and bore a very small proportion to the mass of the bed; and this might account for the absence of the chert.

1.



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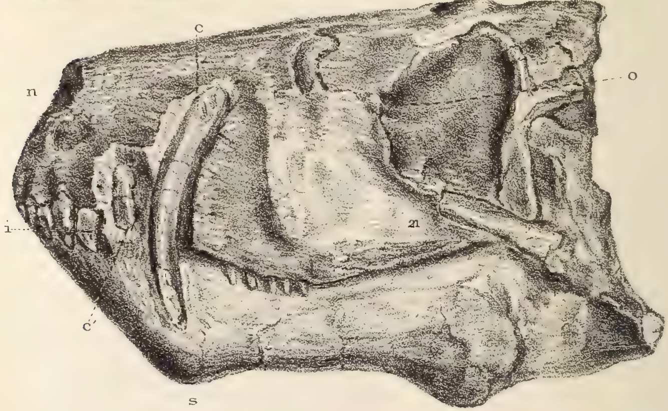

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ÆLUROSAURUS FELINUS

19. *On the Order* THERIODONTIA, *with a Description of a new Genus and Species* (ÆLUROSAURUS* FELINUS, *Ow.*). By Prof. OWEN, C.B., F.R.S., F.G.S. (Read March 9, 1881).

[PLATE IX.]

OF Permian and Triassic Reptilia the most interesting, those that help to fill the hiatus separating the mammalian Marsupials from the cold-blooded Vertebrates, seem to me to be the extinct species constituting, or referable to, the Order THERIODONTIA.

To the characters of this Order given in my 'Catalogue of the Fossil Reptilia of South Africa'†, viz. "Dentition of the Carnivorous type, incisors defined by position and divided from molars by a large laniariform canine on each side of both upper and lower jaws," may now be added "dentition 'monophyodont'"‡. At least I have not had evidence of an immature specimen showing a milk-series of teeth to be succeeded by a permanent series; but if such should be found in any of the extinct Reptiles of the present Order, such Order will be "Diphyodont," like the Mammalian Carnivora; for there is no evidence of any third set of teeth to follow those which may have been preceded (though I doubt it) by a first or deciduous set. Of the adult dentition, whether it be "first" or "second," the molars, as a rule, are inferior in size to the incisors, as both are markedly less than the canines. Add to these characters, "humerus perforated by an entepicondylar foramen"§.

The Reptiles so distinguished or characterized are already referable to several genera; and although I fully recognize the artificial character of a more or less forward extension of the ossified "septum narium," there was a convenience in disparting the Theriodont genera known in 1876 into "Mononarialia" and "Binarialia"‖.

At that date the "Mononarials" included *Cynodraco* ¶, *Cynochampsa* **, *Cynosuchus* ††, *Galesaurus* ‡‡, *Nythosaurus* §§, *Scaloposaurus* ‖‖, *Procolophon* ¶¶; the "Binarials" included *Lycosaurus* *** and *Tigrisuchus* †††. *Gorgonops* ‡‡‡ manifested a third narial modification.

To this series have since been added species referable to some of the foregoing genera, and, also to a genus *Titanosuchus* §§§. The latter was founded on fragmentary fossils not yielding a narial cha-

* Gr. αἴλουρος, cat; σαῦρος, lizard.

† 4to, 1876, p. 15.

‡ Anatomy of Vertebrates, 8vo, 1866, vol. ii. p. 268.

§ Ib. p. 19, pl. xix. figs. 2 & 3 *k*, *h*; Quart. Journ. Geol Soc. August 1876, p. 361, cut, fig. 2, *h*.

‖ Catalogue, *ut supra*, pp. 15, 17.

¶ Ibid. p. 19.

** Quart. Journ. Geol. Soc. vol. xvi. 1860, p. 61, pl. iii.

†† Catalogue, *ut supra*, p. 21.

‡‡ Quart. Journ. Geol. Soc. vol. xvi. 1860, p. 58, pl. ii.

§§ Catalogue, *ut supra*, p. 24.

‖‖ Ibid. p. 24.

¶¶ Ibid. p. 25.

*** Ibid. p. 15.

††† Ibid. p. 17.

‡‡‡ Ibid. p. 27.

§§§ Quart. Journ. Geol. Soc. vol. xxxv. 1879, p. 189, pl. xi.

racter; and with *Titanosuchus*, for the same reason, may be cited Kutorga's *Brithopus* and *Orthopus*, from Russian Permian, V. Meyer's *Urosaurus*, Fischer's *Rhopalodon*, Eichwald's *Deuterosaurus*, and Twelvetrees's *Cliorhizodon*, from the same zone and locality; to the Theriodontia belongs also *Bathygnathus* from the Trias of "Prince Edward's Island," North America*.

To add to this series of Theriodont genera, and, seemingly, to the "Mononarial" section, I now submit to the Society evidence of another genus, *Ælurosaurus*, exemplifying in a clear manner the typical Theriodont characters, under modifications generically distinct from those of the specimens above cited.

It is a skull, including both upper and lower jaws, with the orbits, obtained by Mr. Thos. Bain from the Trias of Gough, in the Karoo district of South Africa, and in the usual petrified condition of the fossils of that formation and locality. The postorbital part of the skull is broken away, and the border of the nostril has been slightly fractured; but the rest of the specimen, with the dentition, is instructively preserved.

The nostril (Pl. IX. figs. 1 & 2, *n*) is terminal and vertical, and shows no part of a septum; in shape it is a full transverse ellipse; what remains of the outlet yields in breadth 13 millim., in depth 9 millim. Each orbit (ib. ib. *o*) gives a full obliquely vertical ellipse, 25 millim. by 20 millim. The facial part of the skull extends two and a half times the fore-and-aft diameter of the orbit in advance of that cavity. The breadth of the upper jaw a little behind the nostril is 26 millim., and gradually increases to 35 millim. near the orbits. The upper surface of the antorbital part of the skull is moderately convex; the sides are less convex, but not flat; the vertical extent of the upper jaw at the middle of the molar series is 34 millim., and decreases to 20 millim. above the incisors.

The skull has been subject to slight distortion; but as this has been effected without fracture, it may be concluded to have been due to forces operating on the matrix after petrifaction, and when the fossil was so encased as to be equally supported on every side during the movements of the bed, such partial pressure having chiefly affected the left orbit (ib. fig. 3, *o*) and a small part of the same side of the skull in advance of it. From the degree in which the sutures are obliterated, I conclude it to have come from a full-grown and probably old individual, the state of the dentition supporting that inference.

The premaxillo-maxillary alveolar border, as it recedes from below the nostril, follows a slightly sinuous course, concave above the incisors, convex above the canine and the molars; thence straight to beneath the orbit.

The mandible is preserved, with the mouth close-shut; and the mandibular teeth are hidden by the overlapping ones of the upper jaw, requiring the sections made in two places for exposure (ib. fig. 3, *c'*). The symphysis mandibulæ (ib. fig. 3, *s*) is 27 millim. in depth and 20 millim. in breadth where it is crossed by the upper

* Quart. Journ. Geol. Soc. vol. xxxii. p. 352, 1876.

canines. From its fore border, formed by the incisive alveoli, it slopes downward and backward, curving more directly backward where it terminates below. All trace of a median symphysial suture is obliterated. The breadth of the mandible where the rami diverge from the symphysis is 20 millim. The preserved length of the mandible is 3 inches 3 lines; and this was probably that, or nearly that, of the skull.

The suture between the maxillary (ib. fig. 1, 21) and malar (26) is distinct, and shows the slender pointed hind end of the maxillary terminating below the middle of the orbit, the lower or malar boundary of which is here 8 millim. in depth.

Before the vertical parallel of the hind border of the orbit is reached, the malar abruptly descends (ib. fig. 1, 26) at almost a right angle to near the lower border of a deflected part of the mandible. This descending part of the malar is broken off on the left side (ib. fig. 3); and the mandibular depression which received it is there exposed.

The mandibular ramus continued backward from the symphysis is subcompressed, 12 millim. in depth beneath the middle of the molar series, thence rapidly gaining depth, especially by a descent and slight inflection of the lower border; the corresponding rise of the coronoid plate is concealed by the malar. At the part where the vertical extension of the mandibular ramus begins there is a low tuberous outswelling of the external surface, behind which that surface gradually sinks and describes a moderate concavity to the angle of the jaw.

A suture indicative of angular and surangular is not visible, but that dividing such elements of the mandible from the dentary one is manifest, as is also, along the lower narrow border of the ramus (ib. fig. 3) the suture between the splenial and dentary, showing the splenial to contribute to the hind part of the large and strong symphysis (*s*) supporting the lower incisors and canines.

The upper incisors (Pl. IX. figs. 1 & 3, i 1-5) are ten in number, five in each premaxillary, arranged in a semicircle or part of a broad ellipse (fig. 3, *i*). The bases of the crowns are in contact, save between the outermost and next tooth in advance.

There is but little difference in size; the first and last in each premaxillary are the narrowest, the second and third the broadest; the exserted crown is best preserved in the fourth and fifth of the right side (fig. 1), and in the fifth of the left side, the basal breadth being $2\frac{1}{2}$ millim., the length about 10 millim.; they all appear to have had the same simple laniariform character. When entire they passed in front of and covered or concealed the crowns of the lower incisors, the base of one of which is exposed behind the fractured crown of its homotype above.

After an interval of 8 millim. extent the crown of the upper canine (ib. *c*) extends downward, and with a feeble curve backward, along a depression of like size and shape on the outer surface of the mandible, which gains breadth for the socket of the lower canine (fig. 2, c') at the fore part of the depression for the reception of the upper one.

The breadth of the base of the exserted crown of the upper canine is 5 millim.; it rather suddenly narrows to the pointed end; the length of the preserved exserted crown is 12 millim., a small part of the apex being wanting. The crown is slightly compressed, with a trenchant border on the hinder part which inclines somewhat inward; there is an indication of a fine crenation of this border.

On the left side (Pl. IX. fig. 2) I had the outer alveolar wall of the canine removed and exposed its root (c), extending upward and slightly backward for twice the length of the exserted crown. The root, as it rose, slightly expanded beyond the breadth of the crown, and as gradually and slightly narrowed to the open end of the pulp-cavity. There is not a trace of a successional canine; and the condition of the pulp-cavity and petrified pulp, discoloured by the iron of its blood, indicates renewal of the working part of the laniary by continuous growth. In the course of this expository operation the exserted crown of the mandibular canine (ib. c') was exposed, 12 millim. in length, nearly that of the corresponding part of the maxillary canine, in front of which it extends, but along the inner or median level, so as to have been wholly concealed (as shown on the right side, fig. 1) by the alveolar plate continued from the upper canine to the upper and outer incisor. There are few instances of carnivorous air-breathers in which the mandibular teeth are so completely covered and hidden by the upper jaw, when the mouth is closed, as in this and other Theriodont Reptiles.

After an interval about equal to that between the upper canine and outer incisor, the molar series (ib. figs. 1 & 2, m) commences, behind the canine. Of this series the crowns of five are exposed on each side of the upper jaw; they are all of the simple, slender, laniary type; the four anterior ones are divided by intervals of about the basal breadth of those teeth, which is $1\frac{1}{2}$ millim. in the first and second molars, and diminishes to 1 millim. in the fifth; the crown, inclining a little backward in the three hindmost, gradually narrows in each molar to a sharp point; the alveolar extent of the five molars is 7 millim.

The toothless extent of the maxillary to beneath the fore border of the orbit is 13 millim. The upper dentigerous tract in a straight line from the foremost incisor to the hindmost molar is 45 millim.

On a cursory comparison of the Theriodont genera and species now made known we discern a considerable range of variety in both size and shape.

The extremes of size are exemplified by *Titanosuchus ferox* * and *Scaloposaurus constrictus* †; those of shape by the flattened head of *Galesaurus* ‡ and the compressed head of *Ælurosaurus* (Pl. IX.). The skull of *Procolophon* § is broad in proportion to its length; that

* Quart. Journ. Geol. Soc. vol. xxxv. (1879), p. 189, pl. xi.
† Catalogue, *ut supra*, p. 24, pl. xvi. figs. 10–15.
‡ Quart. Journ. Geol. Soc. vol. xvi. p. 58, pl. ii.
§ Catalogue, *ut supra*, p. 25, pl. xx. figs. 4–7.

of *Gorgonops* * is narrow; but the ordinal characters are manifest in all; only in the dwarfer and weaker species the relative size of the canines decreases, as is the case with similar carnivorous Mammals.

Galesaurus planiceps and *Ælurosaurus felinus* form an equal-sized pair of these ancient Triassic precursors of our existing cats, or rather cat-like Marsupials. *Galesaurus* had $\frac{4-4}{}$ upper incisors like *Dasyurus*; *Ælurosaurus* had $\frac{5-5}{}$ upper incisors like *Didelphys*; but the molars of the foregoing and other Theriodonts indicate the lower or earlier type that bore them in their simple acuminate form as in the antecedent teeth; they had not advanced to the more complex modified character shown in the molars of the most carnivorous of either marsupial or placental Feræ. *Galesaurus* had as many as $\frac{12-12}{12-12}$ of such molars; in *Ælurosaurus* they did not exceed, or at most by one, the $\frac{5-5}{5-5}$ manifest in the fossil here described.

Galesaurus, in the subject of the paper in the 16th volume of our 'Quarterly Journal,' still has the advantage over all the subsequently discovered Theriodonts in the entireness of the skull, especially in the occipital region; and we may infer, analogically, a repetition of the reptilian characters of the cranium, indicative of low cerebral development, in its coordinates.

If we next compare *Ælurosaurus* with the skull of *Lycosaurus curvimola* †, which, at the date of its extrication, was the next in completeness to that of *Galesaurus*, we find the nearer affinity to *Ælurosaurus* in the small number of molars, in the general proportions of the skull, and in the extent and slope of the symphysis mandibulæ; but the incisor-formula is Dasyurine, and the facial part of the septum narium is prominently manifested. But, of all the previously described genera of Theriodontia I deem *Lycosaurus* to have had the nearest kinship to *Ælurosaurus*.

I am indebted to Sir Bartle Frere, K.C.B., for kindly taking charge of, and placing in my hands, the unique subject of the present paper ‡.

EXPLANATION OF PLATE IX.

Ælurosaurus felinus.

(All the figures are of the natural size.)

Fig. 1. Right side view of the skull.
2. Left side view of the skull.
3. Under view of the skull.

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* Catalogue, *ut supra*, p. 27, pl. xxi. † Ibid. p. 71, pl. 78.

‡ For the discussion on this paper, see p. 270.

20. DESCRIPTION *of* PARTS *of the* SKELETON *of an* ANOMODONT REPTILE (PLATYPODOSAURUS ROBUSTUS, Owen). Part. II. *The* PELVIS. By Prof. OWEN, C.B., F.G.S., &c. (Read March 9, 1881.)

[PLATE X.]

THE pelvis of *Platypodosaurus*, which has been relieved from the matrix since the communication of the former paper*, includes five sacral vertebræ (Pl. X. fig. 1, 1–5), the right "os innominatum," 62–64, and a large proportion of the iliac constituent of that of the left side. Of the first, or foremost, sacral vertebra, s^1, the part of the centrum in advance of the transverse processes, d^1, is broken away, but so as to show the apex of the anterior conical articular cavity. The lumbar vertebra, which was articulated therewith, but had become dislocated therefrom, is preserved in the contiguous matrix; and the shape and depth of the articular cavity of its centrum are exposed (Pl. X. fig. 5).

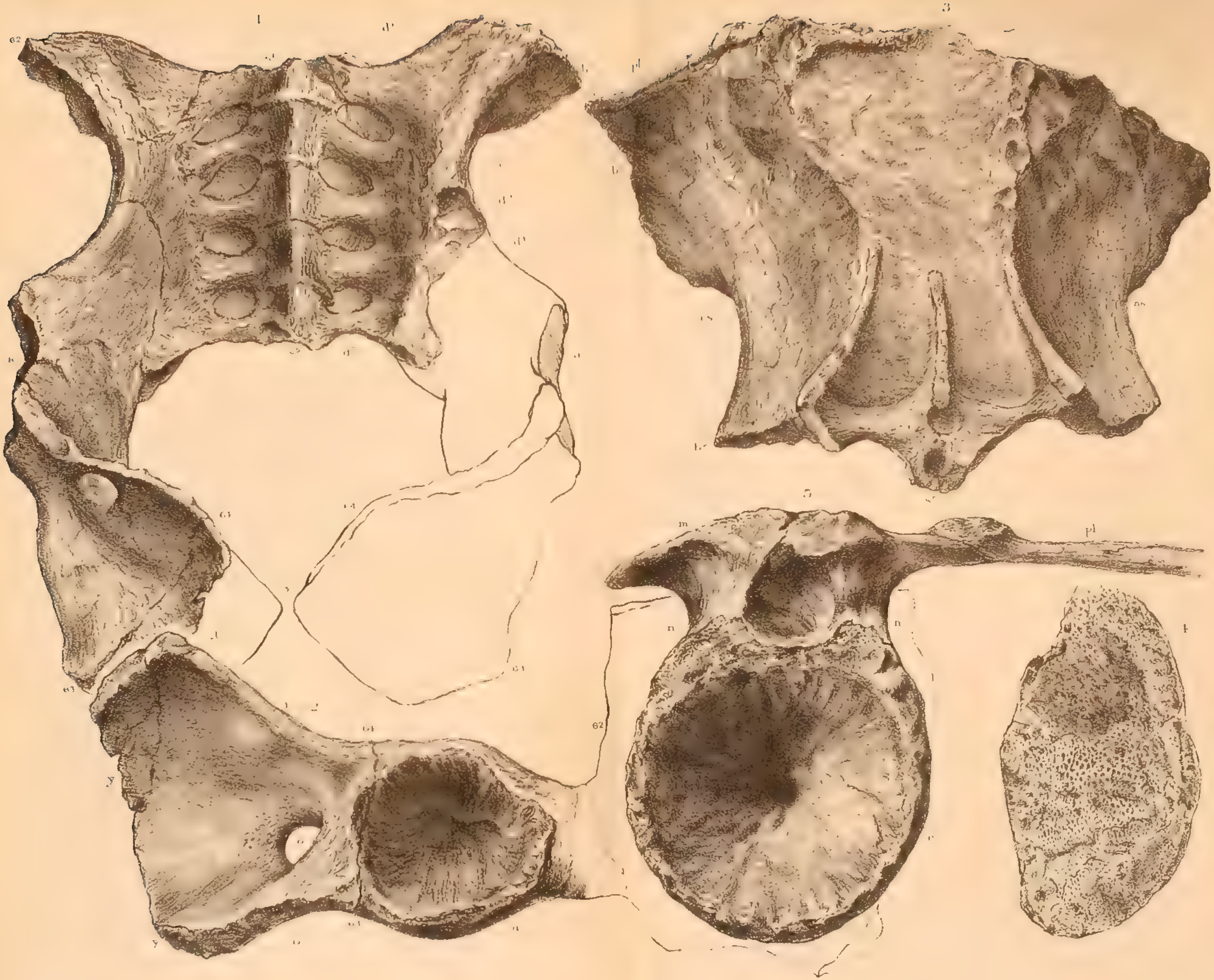
The transverse process of the first sacral, *d* 1, including both di- and pleurapophysial elements, is short and massive: measuring one inch and a half in antero-posterior diameter at its middle and narrowest part, it rapidly expands to its articulation (and what appears to be its confluence) with the ilium, 62. Behind the transverse process the centrum is moderately constricted, but expands to form the joint with the second sacral, of which joint the transverse diameter is 2 inches. The breadth of the entire vertebra is $4\frac{1}{2}$ inches.

The centrum of this second sacral vertebra (*s* 2) shows a greater degree of constriction and a narrower inferior or ventral surface. The transverse process (ib. fig. 1, *d* 2) extends from the anterior two thirds of the upper part of the side of the centrum, is narrower than that of the first sacral, but is longer, curving outward and backward, expanded at both ends, but most so where it abuts against the ilium. The breadth of the second sacral is 5 inches. The line of confluence with and abutment against the ilium is better marked than in the preceding vertebra.

The centrums of the third and fourth sacrals are less expanded at their mutual junction than are those of the first and second vertebræ. The transverse processes are rather shorter, as in that of the third sacral, and this is narrower than those of the second and fourth vertebræ; that of the fifth sacral is the narrowest.

Each transverse process of the sacrum expands at its outer end so as to touch the contiguous one where it joins or coalesces with the ilium. The foramina or vacuities so circumscribed decrease in size from the foremost to the third pair, and change the oblong for the subcircular figure. The hinder articular end of the fifth sacral centrum, *s* 5, is broken away, but in a minor degree than the fore

* Quart. Journ. Geol. Soc. for August 1880, vol. xxxvi. p. 414, plates xvi. & xvii.



A. S. Foord del. et lith.

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PLATYPODOSAURUS ROBUSTUS.

part of the first vertebra; and a larger proportion of the articular concavity is there preserved. The entire breadth of this vertebra is $4\frac{1}{2}$ inches.

Turning to the dorsal aspect of the sacrum (Pl. X. fig. 3), the hinder end of a lofty but narrow crest of bone, *n s*, due to confluence apparently of the neural spines of the fourth and fifth sacrals, has been worked out. The entire breadth of the fifth sacral vertebra is 5 inches. The condition of the spines of the antecedent sacrums could not be determined. In the portion of a Dicynodont sacrum described in the 'Transactions of the Geological Society,' 2nd series, vol. vii. pl. xxxiii. figs. 4 & 5, the short and thick spines of the first and second sacrals are distinct, not confluent.

The section of the circular area of the neural canal of the fifth sacral of *Platypodosaurus* gives a diameter of 6 lines; that of the first sacral has a diameter of 9 lines; that of the last lumbar vertebra one of 8 lines. Thus we have an indication of an expansion in the sacral region for the lodgment of the part of the myelon transmitting the nerves to the pelvic extremities, which accords with the development of the limbs indicated by the femur of *Platypodosaurus* *. Comparing the sacrum above described with that of the larger and more entire pelvis, the subject of a paper in the 'Geological Transactions' above quoted, I incline to regard "five" as the total number of the sacral or pelvic vertebræ in *Platypodosaurus* †.

The degree of coalescence of these vertebræ is such as to sustain the anthropotomical or mammalian consideration of the coalesced mass as one bone or "sacrum;" but the ventral outlets are relatively larger and the wings consequently less ossified. The general shape, moreover, is quadrate rather than triangular, with deeper lateral concavities between the subcarinate bodies and the iliac bones. The present Reptilian sacrum consequently comes nearer in shape to that of the Megatherioid mammals: but it includes fewer vertebral constituents.

The length of such "sacrum" in *Platypodosaurus* is $7\frac{1}{2}$ inches; its breadth, greatest at the third vertebra, is $5\frac{1}{2}$ inches; it is consequently more mammalian in character than is the sacrum of *Dicynodon* ‡. In this larger example of the South-African reptilian pelvis the sacral centrums are more constricted between the articular ends, which are concomitantly more expanded. The space between these sacral bodies and the "ossa innominata" is relatively greater; the transverse processes are consequently longer, and retain more of the ordinary reptilian rib-like character.

The iliac bone in *Platypodosaurus* rapidly expands from its attachment to or confluence with the first sacral transverse process; it extends and curves forward, outward and dorsad, with the convexity mesiad, the concavity lateral. The extreme breadth is $4\frac{1}{2}$ inches; and the anterior margin of the ilium runs almost parallel with the

* *Loc. cit.* p. 422, pl. xvii. figs. 6 & 7.

† Compare also with page 40, plate xxxvi. (pelvis of *Dicynodon*), in the 'Catalogue of Fossil Reptilia of South Africa,' 4to, 1876.

‡ *Loc. cit.*

portion of the long, slender, last lumbar rib (Pl. X. fig. 5, *pl*) here preserved. The outer border of the above expanse of the ilium is produced into a narrow margin; but this subsides at the level of the articulation with the second sacral vertebra, where the ventral border of the ilium becomes thick, smooth, and convex. It thins off to the dorsal border, which is here sharp; and the breadth of the ilium is reduced to $2\frac{1}{2}$ inches. As the bone recedes it assumes a columnar character, with an oval transverse section, gradually expanding, where the right innominatum has been fractured, opposite its junction with the hinder sacrals, to a dorso-ventral diameter of $2\frac{1}{2}$ inches, and a transverse one of $1\frac{1}{2}$ inch (ib. fig. 4).

The expansion of the bone after quitting the sacrum rapidly augments to the acetabulum (ib. fig. 2 *a*), to which it contributes the anterior and dorsal walls, the posterior and postero-ventral wall (completing the circumference of the cup) being formed by the ischial, 63, and pubic, 64, constituents of the "os innominatum." The breadth of the iliac part of the acetabulum is 4 inches; the diameter of the outlet of the cavity is 3 inches. There is a well-marked oblong fossa, $1\frac{1}{3}$ inch in breadth, at the bottom of the cavity. The depth of the cavity here is $1\frac{1}{2}$ inch; and the wall is entire, and nearly an inch in thickness.

The ischium, Y, contributes a rather larger share to the cavity (Pl. X. figs. 1 & 2, 63) than does the pubis. Beyond the acetabulum the ischium contracts to a breadth of 2 inches 4 lines, where it may contribute to the foramen (ib. fig. 2 *o*). This is subcircular and an inch in diameter. Beyond the foramen the ischium loses thickness and gains breadth; but the confluence with the correspondingly lamellate pubis is such as to leave no trace of their relative shares in forming either the above foramen or the ventral wall of the pelvic outlet. This wall, 6 inches in breadth, is strongly concave outwardly, convex towards the pelvic cavity; both surfaces are smooth; and the plate of bone so formed thins off to a symphysial border from from three to four lines in thickness, and probably four inches in extent.

The pubis (ib. figs. 1 & 2, 64) gradually thins and expands as it passes from the acetabulum to the foramen, *o*. The border forming the subacetabular "brim of the pelvis" is from 7 to 8 lines in thickness; its border has been chipped; but, though not entire, it is free from any indication of pectineal process, or of a prominence for the support of a marsupial bone. The utmost care in exposing this part of the pelvis failed to bring to light any such bones, or portions of them.

An accidental fracture, after exposition of the above-described part of the pelvis, about 2 inches in advance of the acetabulum, gives the transverse section (Pl. X. fig. 4) of that most contracted part of the iliac constituent.

The dorso-ventral diameter of the anterior outlet of the pelvis is 8 inches; the extreme transverse diameter is $5\frac{1}{2}$ inches.

The place of the ischiadic notch, *i*, which in most Bruta becomes a foramen, is marked only by a feeble concavity of the postacetabular border of the ischium : the "tuberosity" is indicated at *t*, fig. 2. The extensive ischio-pubic symphysis (fig. 2, *y*, *y*) may have been obliterated by continuous ossification, as in the pelvis of *Dicynodon* above compared*, where it projects, ridge-like, between the broad, outwardly concave, ischio-pubic plates. The parts of the dorsal surface of the plates of *Platypodosaurus* exposed in the block of matrix show the hinder half of a continuous crest of bone (ib. fig. 3, *n s*), due to confluence of the neural spines of the third, fourth, and fifth sacrals. It may have been continued further forward.

The last lumbar vertebra (ib. fig. 5) shows the hinder concave articular surface of the centrum, *c*, which is 2 inches 3 lines in diameter. The margin of the concavity is thick and convex, as in the dorsal vertebra (*loc. cit.* p. 414, pl. xvi. fig. 3) of the preceding paper on *Platypodosaurus*. The neural canal, *m*, is 7 lines in diameter at its hinder outlet, *m*. The neurapophyses, *n*, *n*, rise to 10 lines before sending off the diapophyses, which are broad and flat above, and give attachment to a slightly curved pleurapophysis, *pl*, $4\frac{1}{2}$ inches in length and 9 lines in breadth ; at its free end it almost comes into contact with the iliac labrum.

Of all the examples of pelvic structures in extinct Reptilia which have come under my observation, the type of pelvis exemplified in *Platypodosaurns* departs furthest from any of the modifications of that part of the skeleton known in existing Reptilia, and at the same time makes the nearest approach to the Mammalian pelvis. This is seen, not only in the number of sacral vertebræ, but in their breadth, due to the outward extension of their expanded transverse processes. The Mammalian character is more marked by the breadth of the iliac bones, and by the extent of confluence of the similarly expanded ischia and pubes, together with their further confluence at the ischio-pubic symphysis (which, though the bones are here fractured in the present example, may be inferred to have existed from the general resemblance of the pelvis of *Dicynodon* to that of *Platypodosaurus*).

The small solution of continuity between the ischium and ilium shown by the foramen (*o*, fig. 2, Pl. X.) closely accords with the foramen in a similar part of the pubis of many modern lizards, which gives passage to the "superficial femoral artery." It may, however, if the ischium be actually continued into its periphery in *Platypodosaurus*, be regarded as a trace of a "foramen obturatorium."

EXPLANATION OF PLATE X.

Platypodosaurus robustus.

Fig. 1. Front view of pelvis : $\frac{1}{4}$ nat. size.
2. Side view of acetabulum, ischium, and pubis : $\frac{1}{4}$ nat. size.
3. Back view of sacrum and iliac bones : $\frac{1}{4}$ nat. size.
4. Section of ilium anterior to the acetabulum : nat. size.
5. Back view of last lumbar vertebra : nat. size.

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* *Loc. cit.*

Discussion.

Mr. Hulke asked if the lateral view of the pelvis of *Platypodosaurus* really bore out the view of the author as to its remarkable Mammalian affinities, and especially whether the acetabulum is in front of or behind the vertical of the sacro-iliac junction. He further remarked that most reptiles have not one but many series of teeth; and such would seem to have been necessary for carnivorous animals, in which the teeth are continually liable to damage. He stated that the canine described in this specimen seemed different from what had been described as characteristic of the order Theriodontia.

Prof. Seeley inquired whether the ilium of *Platypodosaurus* resembled that of a Seal. So far as he could judge from the single diagram, the whole pelvis closely resembled that of *Dicynodon*; and if so, its affinities with other orders of fossil reptiles were more important than its presumed analogies with the Mammalia. This type of pelvis was approximated to by certain Dinosaurs, and, but for their prolonged iliac bones, was even more closely paralleled by the pelvis of some Solenhofen Pterodactyles. Even should the marsupial bones suspected by Prof. Owen have existed, the character need not be mammalian, since it is well developed in the Pterodactyle group.

With regard to the Theriodontia, he was unable to admit the importance of the characters and presumed characters on which the order was founded. The teeth of existing Lizards would, by the variety of types which they present, as well sanction ordinal subdivisions as the Anomodontia. The Dinosaurs also, with their carnivorous and herbivorous types of teeth, presented greater variety among themselves than that which was held to separate the fossil described from its Anomodont allies. He could not see how the circumstance of the so-called canine tooth being better nourished and growing larger could in these animals be an ordinal character. He thought it premature to infer the absence of successional teeth as an ordinal character—because the animals described were mature, and succession of teeth may well have occurred in early life. Not only were there no such characters dividing these animals from Anomodonts as separate Crocodiles from Lizards or Turtles from Crocodiles, but there was absolutely no important difference of plan in the structure of the skulls of Anomodonts and the so-called Theriodonts. Prof. Owen had long ago classed these animals as Cynodontia, forming a family of the Anomodonts; that classification he thought excellent, but he could not accept the family as an order or adopt its new name.

Mr. Twelvetrees had just returned from the district of widely spread Permian deposits of Russia. So far as he knew, these rocks had only exhibited two types of Reptilian structure, the Labyrinthodontia and the Theriodontia. He asked for information as to the relations between the latter and several genera described by Prof. Cope.

Prof. Owen said that the sacrum of the Dinosaurs approached that of birds rather than that of mammals. He was not aware of any Pterodactyle pelvis which resembled that of *Platypodosaurus.* He admitted that the dentition of the Lizards varied, but asserted that it never approached to that of the Theriodontia, in which the teeth were not ankylosed to the jaw. He was not able to compare these forms with the genera of Prof. Cope, in the absence of sufficiently large and detailed figures to illustrate the descriptions given by that naturalist.

21. Additional Observations *on the* Superficial Geology *of* British Columbia *and* adjacent Regions. By George M. Dawson, D.Sc., F.G.S., Assoc. R.S.M., Assistant Director of the Geological Survey of Canada. (Read March 9, 1881).

Contents.

In two papers previously communicated to the Geological Society, the results of observations on the glaciation of the northern portion of the American continent from Lake Superior to the Pacific have been given *. The geological work of which these observations formed a part was carried on first in connexion with the North-American Boundary-Commission Expedition, and subsquently on the Geological Survey of Canada. In continuing the exploration of British Columbia on the Survey last named, during the seasons of 1877, 1878, and 1879, many additional facts of interest have been gathered, which it is proposed here briefly to summarize and discuss with special reference to the second of the two papers above mentioned, in which a description of the salient physical features of the province of British Columbia has been given, and a map published; to these, which it is unnecessary here to repeat, reference should be made in considering the points now brought forward.

Observations on the Southern part of the Interior of British Columbia.

In the more detailed examination of that part of the southern portion of the province extending from the Fraser eastward to the Gold ranges, and including the whole breadth of the region formerly called the interior plateau, traces of a general north-to-south glaciation have been found in a number of additional localities at high levels; and it would appear that the ice, whether that of a great glacier or water-borne, pressed forward to, or even beyond, the line of the 49th parallel, notwithstanding the generally mountainous character of that part of the country. With the facts previously recorded, these now extend the known area of north-to-south glaciation to a portion of the plateau over 400 miles in length.

The most striking instance of this general glaciation, and that which carries it up to a height greater than elsewhere observed, is met with in the case of Iron Mountain at the junction of the Nicola and Coldwater rivers. This mountain is one of the more prominent points of that portion of the plateau, which, toward the eastern or inland borders of the coast-range, becomes rough and broken. It rises in a broad dome-like form to a height of 3500

* Quart. Journ. Geol. Soc. vol. xxxi. p. 603, and vol. xxxiv. p. 89.

feet above the neighbouring river-valleys, or 5280 feet above the level of the sea. Its summit has been heavily glaciated, the projecting rocky masses being worn into ridges parallel to the direction of ice-movement, the indicated direction of which is nearly parallel to a bearing N. 29° W. to S. 29° E. If not due to the general glaciation, these markings can have been caused only by ice from the coast-ranges; and though ice has flowed from these as from the other mountain masses of the province during the later portion of the glacial epoch, I believe the situation of Iron Mountain to be such as to preclude altogether this mode of explanation. The mountains of the coast-ranges are neither high enough nor so near as to supply a body of ice capable of overriding it.

On the plateau south of Kamloops glaciated surfaces have been found in several places at an elevation of about 3200 feet above the sea. The locality is far removed from any mountain-ranges capable of giving rise to extensive glaciers, being situated in the very centre of the interior plateau. The rocks are broadly ice-shaped and not unfrequently polished, more rarely distinctly striated. The direction of movement varies from S. 6° E. to S. 27° E. On another part of the plateau, north of the course of the upper part of the Nicola River between Stump and Douglas Lakes, at an elevation of about 3622 feet, are glacial traces similar to the last, consisting of polishing and striation without fluting, having a general direction of S. 9° E. Still another instance of this general glaciation is found on the granite rocks near Chain Lake, between Lake Okanagan and the Similkameen River, in latitude 49° 40′ N. Here, as in the cases before mentioned, the circumstances seem entirely to preclude any explanation by local glaciers, as the portion of the plateau on which it occurs is fully up to the general level, and surpassed only by a few insignificant hills at a considerable distance. The rock-surfaces are beautifully polished, and show striation varying in direction between S. 20° E. and S. 28° E., but no deep grooving. The elevation is 4075 feet.

The Okanagan valley has been alluded to in the paper already referred to as the most important southern gateway of the interior plateau. The bottom of this valley, where it crosses the 49th parallel, is about 860 feet above the sea-level. It is wide, and must at one time have been much deeper, as its rocky floor is not now seen. It occupies the axis of a general depression of some magnitude, and appears to have carried the drainage of a great part of the interior of British Columbia at a former period. This valley has probably been subject to heavy ice-action during the time of general glaciation; but to what extent the features now found may be due to this, and in how far to a subsequent period when, as a narrow arm of the sea or of a great lake, it carried southward ice produced by glaciers nearer the mountains, it is now difficult to ascertain. Glacial striation was observed descending obliquely from the sides toward the centre of the valley, and also in several places in the valley itself, but in both cases without distinct grooving. The rocks of the sides of the valley are often distinctly *moutonnées*; and, as seen from a distance, those on the lower part of the slopes show flattened outlines, while those higher up are more abruptly rounded and have not been so thoroughly ground down.

The general statements made in a former communication, in reference to the covering of Boulder-clay or unmodified drift spread over the entire area of the interior plateau, are borne out in the region now more particularly in question. From the rearrangement of this material the great systems of terraces subsequently mentioned have been formed.

Details need not be given of the evidence in striation and rock-polishing of the existence of glaciers radiating from the various mountain-systems, though it may be mentioned that some of these seem to have had a very great extension down the lower valleys.

In this southern portion of the interior plateau, terraces are exhibited on a scale scarcely equalled elsewhere. They border the river-valleys, and at greater elevations are found expanding beyond these and attached to the higher parts of the plateau and mountains. None has yet been found here, however, equal in height to that previously described on Il-ga-chuz Mountain in the north at 5270 feet above the sea. Many of the terraces and "benches" of the valleys may be the result of the gradual cutting-down of the river-course in the hollow previously filled with glacial débris; but for others, including more particularly those of the higher levels, no explanation short of the complete flooding of the plateau-region will suffice. Knowing therefore that the water must have stood successively at every lower level, it is of comparatively little importance that in the case of some of the lower terraces it becomes impossible to determine whether they belong to this period of the retreating waters or to a subsequent river-erosion.

In this region the terraces frequently surpass 3000 feet in elevation above the sea-level. The more prominent of those seen on the southward slope of Iron Mountain may be taken as an example of the arrangement of these old water-marks. These terraces are as follows, the approximate heights being given in feet—2386, 3063, 3392, 3611, 3715. It is frequently observed, however, that the occurrence of a terrace at any particular level is merely a matter of local circumstance, probably dependent on the supply of material and other such causes; and in different places not very remote the the scale of terraces often differs. This is illustrated on Okanagan Mountain, situated east of the lake of the same name. On the south side of this elevation the principal terraces were barometrically determined as follows—1862, 2042, 2141, 2645, 2800, 2839 feet; on the northern slope six principal terraces were again observed, as follows—1451, 1579, 1962, 2452, 2553, 2879 feet.

The wide trough-like valleys which traverse the plateau are, over a considerable portion of its extent in the southern part of the province, partly filled with a deposit of white silt or loess-like material comparable with that described under the same name in the Nechacco basin to the north *. It is, however, unconnected with the latter,

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 105.

and at a considerably lower elevation, reaching a maximum height of about 1700 feet above the sea. In the vicinity of Kamloops Lake and in the South Thompson and Okanagan valleys, it is well shown, generally forming the first terraces above the rivers. In origin it is probably, like that of the Nechacco region, a deposit from the turbid waters flowing from glaciers at a time when these had a considerable extension from the various mountain-ranges. At this time, either from general depression of the land, or the damming of the valleys by ice or moraines, a system of winding water-ways, lakes or fiords, must have occupied the main valleys. The heads of these valleys in the Gold ranges still hold long and deep lakes, on the banks of which, where they have been examined (more particularly in the Shuswap region), drift deposits are comparatively unimportant, and the white silts are not found. The fine silty material must have been deposited in somewhat tranquil waters; but it appears difficult to explain its absence from the valleys on the flanks of the Gold ranges. It may be suggested that the currents in the upper parts of the valleys were so strong as to prevent the deposition of the silt; but, apart from the difficulty found in supposing such great bodies of water as the valleys must have held at this time to be in rapid motion, there is no such sudden widening in the valleys at the points at which the silt commenees as might account for the slackening of the current.

It is perhaps on the whole most probable that the basins now occupied by the Shuswap lakes and others in a like position were filled with glacier-ice, from which the water flowed down the long valleys, while the abrasion of the rocky beds of the glaciers supplied in large quantity the material of the silt deposits. From the height at which the silts occur, their greater coarseness in the lower part of the Okanagan valley, and the evidence of current-action in that valley near Osoyoos Lake, it is probable that this depression has served as the main outflow of the white-silt lake or sound. At the last it would appear that the glaciers retreated with considerable rapidity, becoming extinct or dwindling to nearly their present size, and leaving the upper portions of the valleys which penetrate the Gold ranges almost free from débris and ready to form the basins of the lakes which now generally occupy them.

The explanation here adopted to account for the existence of these lakes will, I believe, be found applicable to many in other parts of British Columbia, and is again referred to on a subsequent page. It is the same advanced by A. Helland for Norwegian lakes *. Whether any of the lakes in the region now in question lie in rock basins of glacial formation has not been determined, as the valleys below their outlets are generally filled to an unknown depth with detrital materials.

Observations north of the 54th parallel in British Columbia.

An exploratory survey of the remote region lying between the 54th and 56th parallels in British Columbia and of part of the

* Quart. Journ. Geol. Soc. xxxiii. p. 165.

Peace and Athabasca river-basins to the east of the Rocky Mountains, enables the characters of glacial evidence to be defined further north, and has aided in the decision of some theoretical points referred to in the sequel. Most of the facts observed to the west of the Rocky Mountains resemble so closely those previously described for the regions south and east of this that they do not require lengthened notice. The southward or south-eastward passage of glacier-ice in the valley of Babine Lake is indicated by glacial grooving, while the valley of the Skeena has formed a main channel of discharge of glacier-ice toward the coast. In the mountains between the valley of this river and Babine Lake a somewhat irregular, but still, I believe, distinct terrace-flat was observed on the watershed at an elevation of 4300 feet. Its surface is strewn with water-rounded stones differing from those of the mountains of the vicinity. The region north-east of Stuart Lake, extending to McLeod's Lake and the Parsnip River at the base of the foot hills of the Rocky Mountains, is deeply drift-covered, the surface consisting either of Boulder-clay charged with erratics of varied origin, or terrace-flats formed by its rearrangement. This region lies to the north of and somewhat higher than the Nechaco basin, which is characterized by the white silts of a former paper *. The highest part of its surface crossed by the trail has an elevation of 2900 feet.

In the valley of the Misinchinca, flowing westward from the summit of the Pine pass of the Rocky Mountains, glaciation was observed in a few places parallel to the direction of the main depression. In the Pine-River valley, draining eastward and joining the Peace, no glaciated surfaces were seen—a circumstance which may arise from the comparatively soft character of the rocks.

Peace and Athabasca Basins.

In the comparatively level country drained by the Peace and Athabasca rivers, to the north-east of the mountains, underlain by unaltered rocks of Mesozoic and Tertiary age, the chief evidences of the glacial period are found in the distribution of erratics, and the existence of extensive "drift" deposits. In travelling eastward from the mountains by the Pine-River valley, a remarkable absence of such deposits is noted in that part of the valley which traverses the eastern foot hills; but at the Middle Forks the plateau, with an elevation of 1000 feet above the river, or 3000 feet above the sea, and at a distance of thirty miles from the indurated rocks of the mountains, is strewn with rounded pebbles of quartzite &c. from these rocks, though material of local origin preponderates. Eighteen miles further east, at the Lower Forks, the superficial deposits are much more important, covering the surface of the plateau to a considerable depth, and consisting of gravelly beds passing upwards into finer silty materials; the elevation of the plateau is here 2350 feet. In continuing eastward after passing over a summit of 3300 feet on the line followed, Laurentian boulders which must have come

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 105.

from the axis of these rocks to the east or north-east were first observed, and appear in abundance, at a height of from 2300 to 2500 feet, near the D'Echafaud River, in latitude 55° 45′, longitude 120°.

East of this point the wide Peace-River plateau extends, and the general character of the country in regard to its superficial deposits is so uniform that it is unnecessary to particularize localities in describing it. Its surface is so thickly covered that exposures of the underlying rocks are, as a rule, found only in the larger river-valleys. The lower layers of the drift appear to represent the Boulder-clay of the great plains to the south and east and the northern part of British Columbia to the west; they are sandy clays with boulders and stones in abundance, and their upper surface is somewhat irregular, rising in some places in ridges or broad gentle elevations, which stand out above the newer silty deposits in which a great part of the surface is enveloped. The silt is generally pale grey or fawn-colour, and while in places passing almost into clay, becomes occasionally a fine sand. This sandy covering of the surface is found especially at the southern rim of the Peace basin, near the Athabasca, where the plateau attains an elevation of about 3300 feet (long. 117°). The ridges at this elevation are still thickly strewn with Laurentian boulders.

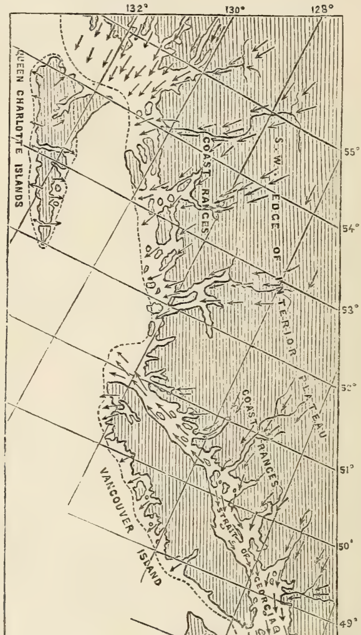
In regard to the material of the drift, the stones and boulders scattered over this great district are, in part, those of the Rocky Mountains to the west, in part derived from the Laurentian axis to the north and east. The fragments from the first-mentioned source are generally of quartzite; the limestone and other softer rocks accompanying these in abundance in the vicinity of the mountains, decreasing rapidly as we recede from them. The Laurentian material is chiefly gneiss and granite of the usual well-marked types. Between the Athabasca and Saskatchewan (long. 113° 30′) the plateau attains a maximum elevation of about 2300 feet, and Laurentian boulders are everywhere exceedingly numerous.

Additional Notes on the Coast.

In the fiords penetrating the coast of the mainland of British Columbia, and channels intervening between the numerous islands lying off it, from the southern extremity of Alaska to the north end of Vancouver Island, marks of the passage of glacier-ice are to be found wherever the rocks are unweathered (see Map, p. 278). These marks are generally in strict conformity with the directions of the passages, which it is evident must have been filled with ice moving in the main seaward from the coast-ranges, in which many smaller glaciers are still found. Whether at any time the supply of ice has been so great as to form a confluent mass flowing toward the sea, at right angles to the general direction of the coast mountains, and without regard to the smaller features of the surface, has not been definitely ascertained; but it is highly probable that this has happened. The outer islands of the Shore archipelago have scarcely been examined; but the little group called the Gnarled Islands (lat. 54° 39′), on the south side of the strait, thirteen miles wide, which lies between

Dundas Island and Cape Fox at the southern extremity of Alaska, shows heavy grooving from N. 50° E. to S. 50° W., proving that this strait must have been filled with ice.

Sketch Map of part of British Columbia, showing the supposed extension and general direction of flow of the glacier-ice when near its maximum limit.



The arrows indicate the direction of flow of the ice.
The dotted line shows the seaward margin of the confluent glacier.

The scarcity of examples of well-marked terraces on the coast, and the comparatively small elevations at which they are found, has been remarked previously. At Fort Simpson, however, in lat. 54° 34′, the surface bears a considerable thickness of detrital matter, and from a distance this appears to form an ill-defined terrace at a height of somewhat over 100 feet. A few miles further southward, at Metlakatla, there is a well-marked terrace, flat, with an elevation, barometrically determined, of 95 feet above high-water mark.

In the previous paper, already several times referred to, evidence was brought forward in favour of a belief that during a part of the glacial period a vast glacier filled the entire Strait of Georgia, which separates the south-eastern part of Vancouver Island from the mainland, and that the ice swept across the south-eastern extremity of the island, and may even have passed some distance southward to Puget Sound, and westward by the Strait of Fuca. It still remained, however, to determine whether the ice supply of this glacier was wholly derived from the neighbouring mountainous country, or whether (as might be supposed in accordance with some theories of glaciation) a great ice-sheet entered at Queen-Charlotte Sound, and passed continuously southward between it and the mainland. It is now found that the last-mentioned idea must be abandoned. In several places about the northern end of Vancouver Island, but more particularly on the little islands of the Masterman group near Hardy Bay, and on those in Beaver Harbour, are marks of very heavy glaciation from south-east to north-west, in bearings varying from N. 49° W. to N. 62° W. This not only passes over the islands, but has grooved, polished, and undercut vertical, or nearly vertical, faces on their south-eastern parts, while the north-western slopes are comparatively rough. These traces precisely resemble those found in the track of the Strait-of-Georgia glacier near Victoria*, and show that here, as there, the ice rode over the low extremity of Vancouver Island. The seaward margin of the continental shore is here also low, and the width of the glacier of Queen-Charlotte Sound can scarcely have been less than twenty or twenty-five miles, and may have been much greater.

Some additional evidence of the movement of the upper parts of the Strait-of-Georgia glacier has been found at Nanaimo, on the inner coast of Vancouver Island, sixty miles north-west of Victoria. Hard sandstone rocks which have been bared on the colliery railway show heavy glacial grooving running parallel to the general trend of the coast and Strait of Georgia in such a way as to prove that the entire strait must here also have been filled with ice. No local glaciation, which would radiate from the mountains of the district, can account for the facts. In clays resting on these glaciated rocks, shells like those formerly observed at Victoria were found, a small collection comprising *Saxicava rugosa*, *Mya truncata*, and *Leda fossa*. The height of the locality is about 70 feet above the sea.

Between Vancouver Island and the mainland, on both sides of the central region from which the ice spread in two directions to form the Queen-Charlotte-Sound and Strait-of-Georgia glaciers, well-stratified deposits of clays and sands occur, in some places forming cliffs 200 feet in height. In the course of the Queen-Charlotte-Sound glacier, Cormorant Island may be cited as an example of these deposits; and in that of the Strait of Georgia, Harwood, Mary, Hernando, and Savary Islands. These deposits resemble those of Victoria, New Westminster, and the islands in the southern part of the Strait of Georgia previously described, but imply for the period of their formation a decreased length in the glacier, from its point of maximum extension, of at least 100 miles. Harwood, Mary, Hernando, and Savary Islands lie about the entrance of Bute and

* Quart. Journ. Geol. Soc. vol. xxxiv. pp. 94, 96, 99.

neighbouring inlets in such a position as to suggest that they may in part represent a moraine marking a stage in retreat of the ice. They form the projecting points of a comparatively shoal bank off these inlets, which, in their upper parts, are very deep. Boulders here occur in great abundance on the beaches, and are probably derived from a Boulder-clay or morainic material underlying the well-bedded deposits.

Glaciation of the Queen-Charlotte Islands.

These islands were the subject of geological examination in 1878. They form a compact archipelago widely separated from the southern extremity of Alaska to the north, and the western coast of British Columbia to the east, and may be regarded as a partly submerged mountain system, the axis of which lies in a N.N.W.–S.S.E. bearing. In its central part summits surpassing 4000 feet, and still bearing patches of perennial snow, are frequent, but it falls at both ends. On the north-east side of the mountain axis, at its north end, is a wide triangular attachment of flat land forming the greater part of Graham Island.

In these islands we find everywhere evidence of the descent of glacier-ice from the mountains toward the sea, but (with one important exception subsequently noticed) none of the passage across the group of any more ponderous ice-mass. The channels and fiords penetrating the southern portion of the islands show in general distinct and heavy glaciation which has evidently been local in character, the scoring and grooving being parallel to the main directions of the valleys, and changing with their course. In Houston-Stewart Channel, separating Prevost and Moresby Islands, the ice has evidently flowed from the axial mountains both eastward and toward the open Pacific to the west. Many of the boulders of the beaches are distinctly glaciated, and, as they lie in some places rudely packed together, seem to have been little disturbed since they were deposited by the ice. Sands, clays, and other detrital deposits referable to the period of glaciation are here almost entirely wanting, and the water round the coast is deep.

Further north, near Laskeek, where the width of the islands becomes greater, there is evidence, in the comparatively slight degree in which the rocks at the outer ends of the inlets are glaciated, that the glaciers did not long stretch much further out than the present coast-line. At Cumshewa Inlet (lat. 53°), and further north at Skidegate Inlet, the character of the coast changes, becoming low; but both these inlets still head in the high axial mountains of the group. Traces of the glaciers of these inlets are found nearly to their mouths; but while the upper parts are still deep and fiord-like, they are partly blocked at their seaward extremities by transverse bars, and shallow water extends far off shore.

Further north a series of fiord-like valleys are still found penetrating the eastern side of the mountainous axis of Graham Island, and the shoal-water found off Cumshewa and Skidegate is represented by the wide stretch of flat land before alluded to. Several of the fiords here open together into a large sheet of water forming the upper part of Masset Inlet, which communicates with the sea to the north by the long narrow passage known as the Masset Sound. The fiords are heavily glaciated, bordered in most places by steep rocky shores, deep and free from drift deposits, and contrast in these respects markedly with the low-shoal eastern shores of the Masset expansion into which they open.

The composition of the low land to the east and north-east is best shown in the cliffs forming its eastward-facing margin. A few miles north of Skidegate a low cliff or bank shows deposits which are evidently of glacial age, cut off above by a gently undulating surface of denudation, above which is 10 or 15 feet of material which shows no sign of blending with that below. The upper deposit consists of sand and well-rounded gravel in regular and often nearly horizontal layers. It has here become in many places quite hard, being apparently cemented by ferruginous matter. Its lower layers hold small boulders, a few of which are from 18 inches to 2 feet in diameter. The lower deposit in one place is a typical Boulder-clay, with many half-rounded or subangular stones and occasional boulders of some size. The matrix is bluish grey, hard, and somewhat arenaceous, the whole being irregularly mingled, and having no distinct bedding. At a short distance this Boulder-clay begins to show bedding, and to become interleaved with hard clayey gravels composed of well-rounded pebbles. The stratification of these is undulating and rather irregular, and there is some local unconformity by erosion between the different layers. A few paces still further on these become interbedded with, and are eventually replaced by, hard, bluish-grey, arenaceous clays, which hold some pebbly layers and an abundance of broken specimens of mollusks, among which *Leda fossa* is the most common. A small *Cardium*-like shell and fragments of a *Balanus* were also observed.

Further north on this coast the clays, with the overlying sandy deposit in greater or less thickness, form long ranges of cliffs; and though locally irregular, their general character continues the same. The clays are, in some places, very hard, and were observed to hold fragments of trees quite brown in colour, but not mineralized. These deposits, as a whole, very closely resemble those previously described as occurring at Victoria, on the south-eastern extremity of Vancouver Island.

Lying like Masset Inlet near the junction of the hilly and low countries is Naden Harbour, and between this and Masset Inlet are two large freshwater lakes, which doubtless occupy an analogous position, but have so far not been visited by any but Indians. Southward there is reason to believe that there are one or more basins in a similar relation between Masset Inlet and Skidegate.

Boulders are very numerous on the coast of some parts of the northern portion of Graham Island; and these and the beach-gravel are in many cases formed of rocks which must have been transported from the mainland to the north or east, and quite unlike those of the Queen-Charlotte Islands. Similar erratics appear to characterize in greater or less abundance the whole of the low country above described, but are not found about the heads of the south-western extremities of Masset Inlet.

It has previously been shown that at the time when the Strait-of-Georgia glacier began to diminish the sea must have stood considerably higher in relation to the land than at present, and the glaciated rock surfaces about Victoria and Nanaimo no sooner appeared from beneath the glaciers than they were covered by deposits holding marine shells. Such must have been the state of affairs also in the Queen-Charlotte Islands; and to this time are doubtless to be referred the clay and sand deposits of the low north-eastern part of Graham Island above described. The material of these must have been supplied from the glaciers of the islands themselves, but added to also (as the nature of the boulders proves) by the débris borne on floating ice from the larger glaciers of the mainland, the sea levelling and spreading abroad the material, and preventing the formation of any well-marked terminal moraines by the island glaciers. The rocky beds of the fiords and Masset-Inlet expansions must have been shaped to some extent by the ice; but the absence of drift material from their areas, and especially of the erratics derived from the mainland, are, with their situation, good reasons for supposing that they mark the regions last covered by glacier-ice, and from which it eventually retreated with some rapidity, leaving the hollows formerly occupied by it to become first inlets, and then, with increasing elevation, in some instances lakes.

The exceptional case which seems to show the impingement on the Queen-Charlotte Islands of ice not produced on them was found on the north coast on the little islands lying outside the entrance to Masset Inlet; but it is probable that similar traces might be found by search in additional localities in this vicinity. Wider exposures of basalt a few feet above high-water mark here show very heavy though somewhat worn glaciation in a direction S. 10° E., or N. 10° W., but probably the former. The depth and parallelism of the grooving would appear to show that it is glacier work. The mountainous axis of the islands in this their northern part does not exceed in height about 1300 feet, and where nearest is about 15 miles from the locality, while the direction of the marking is not that which would be followed by ice descending from the mountains under any circumstances, being more nearly parallel to than radiant from them. It is, however, just that which ice-masses floating up or down the strait separating the islands from the mainland must have taken, or glacier-ice pushing southward from the long fiords of the Prince of Wales group in Southern Alaska, sixty miles distant. It may, I believe, be attributed with greatest probability to the last-named agent; and in view of the great extension which the glaciers of other parts of the coast must at one time have had, that required for the Prince of Wales group and adjacent channels does not appear excessive.

General Remarks and Conclusions.

It is somewhat difficult to connect the various observed facts of the glaciation of British Columbia in a general theory of glaciation, owing to the complexity of its physical features and their marked character. Several conjectural schemes were advanced in a former communication; but, abandoning the seemingly untenable theory of a great polar ice-cap, two probable hypotheses appear to remain. A general north-to-south movement of ice is indicated by striation in a number of places in the central-plateau zone, extending now for a length of over 400 miles. This region, from elevations exceeding 5000 feet downward, is also covered thickly with drift-deposits requiring, by their character and mode of arrangement, the action of water. To account for these facts it was thought that either the flow of strong arctic currents bearing heavy ice during a period of great submergence might be supposed, or that the whole region may have been buried under a massive confluent glacier, the drift-deposits being laid down as it retreated in the water of the sea during a period of subsidence, or in that of a great lake held in by glacier-dams in the valleys of the several mountain-ranges.

It was presumed that the gaps of the Peace and Pine rivers in the Rocky-Mountain range might have sufficed for the entrance from the north-east of such currents and masses of ice as would be required by the first theory; but the examination of the region, with this supposition in view, has convinced me that, notwithstanding the general decrease in elevation and width of the Rocky Mountains, the valleys of the rivers are too narrow and indirect, and the surrounding mountains too high, to allow the inflow of sufficient currents with the degree of subsidence which would be required by most of the localities of glaciation and by the superficial deposits. Neither is there any evidence of the passage of drift-material in this region across the mountains either from east to west or in the opposite direction.

It therefore appears to remain as the most probable hypothesis that a great glacier mass resembling the inland ice of Greenland has filled the region which may be called the Interior Plateau, between the Coast Mountains and the Gold and Rocky Mountain ranges, moving (though perhaps very slowly) southward and south-eastward from the region of great precipitation and high mountains of the northern part of the province*, and discharging by the Okanagan depression and through the transverse valleys of the coast range. It still appears to me most probable, however, that this stage of the glacial period was closed by a general submergence, during which the deposit referred to as Boulder-clay was laid down in the interior plateau, and that as the land again rose it assumed its present terraced character. Conditions may be suggested to account for the temporary existence of a great lake in the interior

* Explorations in the northern part of the province in 1879 have shown that the mountains here are even higher and more extensive than had been supposed, several ranges exceeding 8000 feet in great portions of their extent.

plateau of British Columbia; but this will not explain the great height to which water-action has extended on the east side of the Rocky Mountains*, which was probably synchronous. The last stage of the glacial period in the northern part of British Columbia appears to have given rise to the silts of the Lower Nechacco basin, while on the opposite side of the Rocky Mountains similar deposits were laid down over the Peace-River country, the elevation of the two districts being nearly alike.

The general question of the origin of the drift-deposits of the Great Plains having been fully discussed elsewhere †, it will be unnecessary here to enter into it at length. The most remarkable feature of the glacial deposits of the plains is the Missouri Coteau, which it was supposed ran northward from the region near the 49th parallel, where it was more particularly studied, nearly following the margin of the third prairie steppe. This supposition has since been in great measure confirmed; and on the journey from Edmonton to Winnipeg, in the autumn of 1879, I was able to examine cursorily the character of this feature where it touches the north Saskatchewan near the "Elbow," and to observe the great accumulation of heavy boulders of eastern and northern origin in that vicinity. Further north, the facts now advanced show that with the general lowering of the surface of the country the well-defined zone of drift-deposits known as the Coteau is more or less completely lost, the material being scattered broadcast over the upper parts of the basins of the Peace and Athabasca rivers, and approaching in considerable mass the highlands near the base of the Rocky Mountains.

Over the whole western portion of the plains, from the 49th to the 56th parallels, there is a mingling of the eastern and northern Laurentian débris with that from the Rocky Mountains to the west, the latter consisting largely of certain hard quartzite rocks, and the overlap seeming to imply the existence of a sea in which ice derived from both sources floated freely.

Discussion.

The President spoke of the care with which Dr. Dawson conducted his researches, and the value of his observations.

Mr. Bauerman stated that he was not acquainted with the district described by Dr. Dawson; but he thought, from what he had seen in Oregon and the Columbia valley, that many of the conclusions of Dr. Dawson could be established. He, however, doubted whether the ice had been quite so widely spread as Dr. Dawson supposed. He described some of the great terraces on the Barrier River; there were sixteen, one over the other, on a stupendous scale. He had traced them on the Columbia River to 2300 feet above sea-level;

* Quart. Journ. Geol. Soc. vol. xxxi. p. 618.

† Quart. Journ. Geol. Soc. vol. xxxi. p. 603. 'Geology and Resources of the 49th Parallel,' p. 6.

and they could be found still higher but for the degrading action of the climate. The rapid melting of the snow, followed by freezing, and slipping of the ice then formed, produced well-defined ice-scratches in a very short time.

Prof. Boyd Dawkins said that he had studied the glacial phenomena in America, though he had not been so far north; and, so far as he could form an opinion, that northern area appeared to have been a great area of dispersal of ice. In the Western and Pacific States, however, there was no evidence of a great ice-sheet, only a rather larger extension of local glaciers. On the eastern side the southern boundary of the confused glacial deposits, or the drift, passed from the latitude of New Brunswick in a N.W. direction towards the area of the Mississippi, forming a low range of well-marked hills. To the south of this are the "Champlain terraces" and traces of local glaciers on the higher hills. So that in North America there are two great systems of glaciation—one in the N.W., such as Dr. Dawson had described; and another in the N.E. region, apparently pointing towards Greenland and Labrador.

22. *The* Permian, Triassic, *and* Liassic Rocks *of the* Carlisle Basin. By T. V. Holmes, Esq., F.G.S. (Read February 23, 1881.)

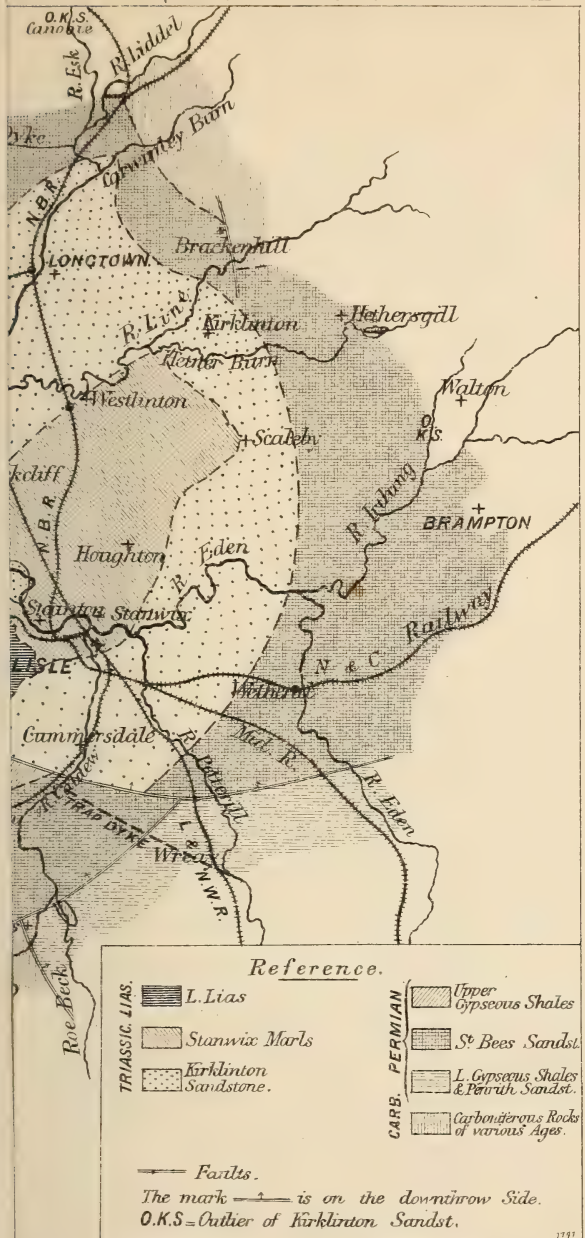
[Plate XI.]

I am enabled, by permission of Prof. A. C. Ramsay, Director-General of the Geological Survey, to lay before you the general results of the Survey examination of the Permian, Triassic, and Liassic rocks in the country bordering the Solway Firth; but I do not propose to discuss here the glacial drift and other superficial beds by which the surface of the ground is almost entirely covered, and which are the main hindrance to an understanding of the rocks which form my subject this evening.

Papers on the Permian and Triassic rocks of the North-west of England have been read before this Society by Prof. Sedgwick, by Sir Roderick Murchison and Prof. Harkness, and by Mr. E. W. Binney. But as few districts promise less, except as regards drift and peat-mosses, than that immediately around the Solway, it has hitherto been dealt with, as awhole, in a brief and cursory fashion. In addition, a knowledge of certain borings, the results of which are by no means generally known, is absolutely necessary to a correct view of the structure of the Carlisle basin (see Map, Pl. XI.).

The lowest bed with which we are here concerned is the great brick-red Upper Permian sandstone, so well shown at St.-Bees Head, and named, therefore, the St.-Bees Sandstone. Between St.-Bees Head and Maryport the coast consists of the underlying Coal-measures, the St.-Bees Sandstone having been swept away by marine denudation. But at Maryport it again becomes visible, its most northerly appearance being below Swarthy Hill, on the foreshore, about midway between Maryport and Allonby. North of Swarthy Hill none but superficial beds are exposed on the southern shore of the Solway. On the Scottish side St.-Bees Sandstone appears at Tordoff Point; but, with this exception, a walk along the coast between the Sark and the Nith shows no more than one between Allonby and Rockcliff, on the southern side. At a distance of one, two, or three miles from the coast-line, however, Scotland has decidedly the advantage, the corresponding part of Cumberland being entirely destitute of sections.

Turning eastward from Maryport, the St.-Bees Sandstone is found to occupy a belt of country ranging towards Dalston on the Caldew and Wetheral on the Eden. Between Maryport and the Caldew its southern boundary consists of Carboniferous rocks of various ages; and between the Caldew and the Eden of Lower Permian beds. The Carboniferous-Permian boundary is almost invariably a faulted one; in Shalk Beck, however, the unconformity between the two formations is very distinctly shown about a mile above East Curthwaite. The boundary between the St.-Bees Sandstone and the Lower Permian beds, between the Caldew and the Eden,



Fredk. Dangerfield Lith. London.

ISLE BASIN.

Fredk Dangerfield Lith. London.

SKETCH-MAP SHOWING THE ROCKS OF THE CARLISLE BASIN.

(Disregarding Superficial Beds.)

Scale 1 2 3 4 Miles

consists of two great faults, which abut against each other at Newbiggin, on the Petterill. Both faults have a downthrow to the north. The more westerly ranges from a point a little north of Rose Castle, on the Caldew, to Newbiggin; the other from Newbiggin to Brackenbank, on the Eden, about two miles above the railway bridge at Wetheral. This Brackenbank and Newbiggin fault is known to exist for many miles eastward of the Eden; it has also (as I believe) a considerable extension westward, in the direction of Cummersdale.

The Lower Permian beds which are cut off by these faults are the Penrith Sandstone, a bright red rock remarkable for the scale on which it is false-bedded, and a red shaly series overlying it, and directly underlying the St.-Bees Sandstone. The Penrith Sandstone is well shown in the Petterill, a little below Wreay Bridge. The junction of the Penrith Sandstone with the overlying shaly beds (which in this locality contain gypsum) may be seen in the little streamlet which runs into the Petterill from the east, after crossing the Carlisle and Penrith road about midway between Springfield and Carleton Hill. A little lower down the Petterill, but just above the road from Newbiggin Bridge eastward, there is a quarry in St.-Bees Sandstone.

North of the faulted line the St.-Bees Sandstone is the only Permian rock seen*. About Brampton it occupies a broad belt of country between the Carboniferous formation on the east and the Triassic rocks on the west. In the Eden it is well shown between Brackenbank and Wetheral Bridge, and thence as far down as the junction of the Eden and Irthing. In the Hether Burn, the Line, and Cardwinley Burn sections are very abundant. In the Line the full thickness of the St.-Bees Sandstone does not appear, owing to Carboniferous rocks being brought in by a fault close to Brackenhill Tower, above which spot no Permian beds are seen; but in the Hether and Carwinley Burns there is an almost continuous series of sections, from Carboniferous rocks below the St.-Bees Sandstone to the Triassic beds above it. In both streams (as in Shalk Beck) a thin breccia is seen at the base of the Permian formation, and there is no fault at the junction with Carboniferous rocks. In the Esk, north of the railway bridge between Scots Dyke and Riddings junction stations, the St.-Bees Sandstone may be seen, on the right bank of the stream, on both sides of the Border-line; it also appears in Moat Quarry and the cliff on the south side of the railway between Moat Quarry and the ancient fortress known as Liddel Strength. West of the Esk it is visible in the neighbourhood of Scots Dyke, both in the Glinger Burn and Sark; also in many parts of the Kirtlewater, south of Kirtlebridge. It is well shown in the railway-cutting on the north side of the road from Annan to Kirtlebridge, in the Annan water about Annan, and at Tordoff Point on the Solway.

The dip of the St.-Bees Sandstone, which varies, as a general rule, from north to north-west between Maryport and the Caldew, slowly

* Except a very thin breccia at its base.

changes between the Caldew and Hether Burn, till, in the latter stream, it is about south-west. It retains this (general) south-westerly dip as far as the Esk, but west of it the dip becomes more or less east of south. At Annan it is nearly due south.

No signs of the Lower Permian formations are visible east of the Annan Water. It is somewhat singular, however, that the Permian rock between the Nith and Lochar Moss, in the neighbourhood of Dumfries, is precisely like the Penrith Sandstone in appearance. It is remarkable for the hardness and thickness of the beds of breccia it contains. The two great Permian sandstones of Penrith and St. Bees are so distinct in character, that there is usually no difficulty in distinguishing them even in hand specimens.

Having traced the St.-Bees Sandstone around the circumference of the Carlisle basin, except where prevented from doing so by the waters of the Solway, the overlying beds now demand attention. First of these come the Gypseous Shales of Abbey Town and Bowness. So thickly and persistently covered by drift is the country immediately around those two places that were the only information obtainable that to be derived from natural sections the existence of the Gypseous Shales would remain entirely unknown; nor, indeed, would there be any reason to suppose the St.-Bees Sandstone to be overlain in that quarter by any thing but glacial drift, peat, and alluvium.

Fortunately, however, two borings come to our aid, one of which discloses the fact that in the neighbourhood of Abbey Town more than 700 feet of Gypseous Shales rest upon St.-Bees Sandstone, and are themselves covered by nearly 200 feet of drift. The other boring was made near the west end of Bowness, at high-water mark, and proves the presence there of 367 feet of Gypseous Shales below 41 feet of drift. It is not absolutely certain that the Bowness boring penetrated to the St.-Bees Sandstone, though it ended in red stone; but it is very highly probable that such was the case, St.-Bees stone being visible a short distance to the north, on the Scottish shore. At Bowness, therefore, the outcrop of the Gypseous Shales is beneath the Solway; east of Bowness it probably ranges, under water, in the direction of Rockcliff Marsh. Towards Silloth, on the other hand, it is most likely outside the present coast-line, against which it may abut in the neighbourhood of Allonby.

The southern outcrop of the Gypseous Shales can only be approximately traced across an entirely drift-covered country by the help of the most northerly exposures of St.-Bees Sandstone. Its general direction is from Allonby to West Newton, and thence to Wigton and Dalston.

East of Bowness and Abbey Town, the only evidence bearing on the existence of the Gypseous Shales is the record of an old boring near Great Orton, to which I shall have again to refer in treating of the Lias. It was made in search of coal in the year 1781. Below rock evidently Liassic was "red stone or clay sometimes mixed with veins of white." This description fits the Gypseous Shales very well, the gypsum in them being in the form of thin laminæ, and beds of any thickness being absent. On the other hand, in no other formation at all likely to be found underlying the Lias at Orton would "veins" of a white substance be found.

But if the Gypseous Shales are neither seen nor recorded as having been bored through east of Great Orton, it may be asked why I have treated them as older than the formation which directly overlies the St.-Bees Sandstone north and east of Carlisle. On this point the evidence certainly leaves something to be desired, though there seems to me to be no doubt on which side the balance inclines. As will shortly be seen, the bed in question (which I have called the Kirklinton Sandstone) rests unconformably on that of St. Bees; while there is neither evidence nor presumption of any kind in favour of the existence of unconformity between the St.-Bees Sandstone and the Gypseous Shales. Again, the presence of gypsum is, so far as it goes, a presumption of Permian affinities, gypsum being found, as I have already mentioned, in the shales underlying the St. Bees stone, while it is not seen in any of the higher beds of this district.

Leaving the almost sectionless district west of the Caldew and Eden till the time comes to treat of the Lias, it will now be most convenient to discuss the sections seen in the first-named stream about Dalston and Cummersdale.

St.-Bees Sandstone is visible on the Caldew at Brackenhow and Buckabank, and here and there nearly as far down the stream as the outfall of the Pow Beck at Dalston. Opposite Dalston Hall the trap dyke, well known at Barrock Fell and Armathwaite, is slightly shown on the right bank, at the spot at which river and railway begin to run side by side. This is the most westerly exposure of this dyke in Cumberland; but as I am informed by Mr. J. G. Goodchild that there is no ground for supposing (judging from his knowledge of it in the Eden-valley district) that it is also a fault of any magnitude, if a fault at all, I need say no more about it here.

A few yards below the dyke, and on the same bank of the river, is a low cliff of greyish sandstone, and it seems to me that in this grey rock we probably have the uppermost beds of the St. Bees. The boring near Abbey Town shows that directly below the Gypseous Shales, and above the typical St.-Bees Sandstone, are about 40 feet of sandstone and sandy shale, mainly grey in colour. No sandstone like this is seen higher up the stream, and the rock next seen below at Cummersdale is evidently not St.-Bees Sandstone at all. In addition, Mr. J. G. Goodchild considers the beds at and below Buckabank to be higher beds in the St. Bees than any he has seen in the Eden-valley district, where the uppermost are cut off by the Penine fault.

The next section, that adjoining the rifle-butts at Cummersdale, disappoints any expectations that may have been formed of at last seeing the Gypseous Shales. Strange to say, they are nowhere visible at the surface. The rock at the rifle-butts is a very soft, red, shaly-looking sandstone, without any sign whatever of the presence of gypsum. Similar rock may be seen here and there in the river-bank, as far down as Cummersdale Print-Works. It is, in short, the Kirklinton Sandstone; but the dip at the rifle-butts is slightly west of north, and, being towards the Caldew, the surface of the low river-cliff is wet and slimy, and the characteristic bright colour and false bedding are both obscured. The soft Kirklinton stone, however, invariably weathers, as at Cummersdale, about, and for a few feet above, the surface of the river, along whose course it is exposed. A comparison of the sections at Cummersdale with those about Kirkandrews-on-Esk and elsewhere will show this very clearly. Fortunately the identity of the rock at Cummersdale is placed beyond dispute by the presence of a small but dry section about 100 yards below the rifle-butts. The spot is marked by the stump of an old tree, at the base of the bank bounding the alluvial flat on the right side of the stream. Here the bright and almost scarlet colour and false bedding are both manifest.

The question arises, in what way the absence of the Gypseous Shales at Cummersdale may be best accounted for. There can be no doubt that they suffered very much from denudation before the deposition of the Kirklinton Sandstone, as their total absence east of Carlisle bears witness. As regards the amount of their extension eastward, there are but two items of evidence. The first is the old boring at Great Orton, already alluded to, in which 132 feet of what were probably Gypseous Shales were pierced and (apparently) their base not reached. The second is a very recent boring at Justice Town or Linehow, about a mile above the junction of Line and Esk. This showed about 170 feet of Kirklinton stone resting directly on that of St. Bees. These borings tend to show that the Gypseous Shales cease to exist more speedily north than south of Carlisle. On the whole, I am inclined to think that the Gypseous Shales would be visible at Cummersdale, but for an extension of the Brackenbank and Newbiggin fault. This, if prolonged westward, might very well cross the Caldew between Dalston Hall and the rifle-butts, cutting off the Gypseous Shales and bringing in the Kirklinton Sandstone on its northern side; just as further eastward we find it bringing down the St.-Bees Sandstone on its northern side against the Lower Gypseous Shales on the south.

The Kirklinton Sandstone is best seen in the parish from which it derives its name, and at Rockcliff and Netherby. I have already described its appearance at Cummersdale. Descending the Caldew it is again visible at Holmhead Bridge. Below Carlisle the upper beds are well shown at Skew Bank, north of Grinsdale, and lower ones at Rockcliff. Ascending the Eden from Carlisle it appears at Rickerby, in the river-bed at Low Crosby, and in the left bank a few yards N.E. of Holmgate. The junction with the St. Bees stone must be between the last-named spot and the junction of the Eden and Irthing.

Between the Eden and Caldew the only evidence is the following. In the Petterill there is a small section, showing rock like that at Cummersdale, a few yards above the house called Petterill Bank; and the record of a boring at Garlands Lunatic Asylum tells us that below 28 feet of drift 277 feet of red stone with white bands were pierced, which seemed to the borer to resemble "Lazonby stone." Now "Lazonby stone" is, in other words, Penrith (the great Lower Permian) Sandstone; but it is in the highest degree improbable that Penrith Sandstone would be found near the surface at Garlands, the natural presumption being that both St.-Bees and Kirklinton Sandstones overlie it there. A very simple explanation, however, suggests itself. The Penrith and Kirklinton Sandstones resemble each other very much in colour, and equally differ in that respect from the St. Bees. Both the Penrith and St.-Bees Sandstones are largely quarried—the former about Lazonby and Penrith, the latter near Curthwaite and Aspatria; but the soft Kirklinton stone is scarcely ever quarried, and is well shown only in localities that are but little generally known or visited. Hence the testimony of the borer, though decidedly against the supposition that the stone in the bore-hole was St. Bees, is not really against the view that it was Kirklinton Sandstone, as I have no doubt was the case. Its outcrop hereabouts will keep a little east of Warwick and west of Scotby and Carleton, abutting against the Newbiggin and Cummersdale fault in the neighbourhood of Brisco Hall.

The Kirklinton Sandstone is nowhere visible in the sectionless country between the Eden and Hether Burn; but in the latter stream it may be seen from Hether-Bank Bridge to its junction with the Line. At and above Hether-Bank Bridge are quarries in St.-Bees Sandstone, the dip being about south-west. At Cliff Bridge, Kirklinton, the Kirklinton Sandstone is extremely well displayed, and it may be seen, on ascending the Line, as far up as Shield Green, between Kirklinton Hall and the Muckle Linn. Between Shield Green and Brackenhill Tower is St.-Bees Sandstone, and above Brackenhill Tower Carboniferous beds (mainly sandstones and shales) are brought in by a fault which ranges nearly north and south, and may be seen crossing the river close to the Tower.

Between Shield Green and Kirklinton Hall a bed appears in the Kirklinton Sandstone much resembling that of St. Bees; and in this harder band are two quarries, one in the northern corner of Hirst Wood, the other on the right bank of the river at Stag Ford. From the dip, these two quarries are in all probability in the same bed, and the St.-Bees-like stone need not be more than about 30 feet thick.

There are no signs of faults, and the St.-Bees-like rock is evidently interbedded with Kirklinton Sandstone of ordinary appearance. This circumstance seems worth noting here, as, combined with the want of any evidence of unconformity between the two formations at Shield Green, it tends towards a totally different view from that pointed at by all the rest of the evidence bearing on the relations of these two beds.

Below Cliff Bridge the Kirklinton Sandstone may be seen as far down as Metal Bridge, a little below the junction of the Esk and Line, being well shown at Westlinton. (I have already mentioned the boring at Justice Town, which showed 170 feet of Kirklinton Sandstone above St. Bees.) Ascending the Esk it appears beneath Longtown Bridge and at various spots in the neighbourhood of Kirkandrews Tower; also about the outfall of Carwinley Burn, and up that stream as high as Carwinley Mill. At the mill the junction with the St. Bees is well shown. It seems to me that there is some slight evidence of unconformity between them at this point, West of the Esk, Kirklinton Sandstone is seen in the lower part of the course of the Glinger Burn, and St. Bees nearer Scots Dyke. All that can be said of its western outcrop is that it must keep a little westward of the various exposures in the Glinger Burn and at Metal Bridge and Rockcliff, and eastward of the Gypseous Shales of Bowness. It probably runs below the Lias in the neighbourhood of Kirk Bampton.

It will be remembered that the Kirklinton Sandstone seen at Cummersdale was invariably red, like that of Kirklinton or Netherby; but at Holmhead, in higher beds, a borehole recorded by Mr. E. W. Binney* pierced through 108 feet of white sandstone, overlying 117 feet (not through) of red. At Carlisle Gaol the borehole was through 250 feet of red sandstone; while at Messrs. Dixon and Co.'s, West Tower Street, I was informed by Mr. John Hamilton that 123 feet of white sandstone were penetrated. Other examples might be given. Lastly, in a boring at Stainton, in still higher beds, 360 feet of white or grey stone were proved above an unknown thickness of red. Thus the Kirklinton Sandstone appears to consist of a lower red, a middle red and white, and an upper white series of beds.

The Stanwix Marls probably nowhere attain any considerable thickness. Their most characteristic colours are red and greenish grey. They vary very much in hardness, stony bands being much more common in some places than others. They lie between Cliff Bridge on the north and Carlisle on the south, Houghton on the east and Beaumont on the west. They are well shown on the Eden in the lower part of the cliff at Etterby Scaur, from the North British railway-bridge to Grinsdale, and about Beaumont, the sections in the two last-named localities being in the left bank of the river. On the Line their junction with the underlying Kirklinton Sandstone may be very plainly seen, both at Westlinton and near Cliff Bridge. At Westlinton it appears in the bank bounding the alluvial flat, a few yards east of the bridge. Nearer Cliff Bridge it is plainly shown in the little plantation bordering the alluvium, about midway between Cliff Bridge and High Alstonby. The marls appear here and there in the little streams that unite and fall into the Line between Low Alstonby and Westlinton; they are visible nearly as far eastward as Stonystonerigg.

Before taking leave of the neighbourhood of Kirklinton, which is, as we have seen, perhaps supreme in geological interest among the localities mentioned in this paper, I may remark that the scenery of the Line above Cliff Bridge is very picturesque for many miles and very different from that below it. Both scenery and geology, how-

* Mem. Lit. & Phil. Soc. Manchester, ser. 3, vol. ii. pp. 343–388.

ever, have hitherto been entirely ignored by writers on the geology of North Cumberland, as well as by the authors of guide-books; for, though Cliff Bridge itself is only about two and a half miles from Longtown or Lyneside stations, trains stopping at those places are few and far between, and every mile higher up the Line increases the distance from the railway by that amount; while eastward lies the lone bare district of Bewcastle, destitute alike of railways and inns.

The extent of the area covered by the marls, south of the Eden, is doubtful, but the evidence available tends to show that it is very small. Though they form the lower part of the cliff at Etterby Scaur, the three new railway-bridges across the Caldew, the lowest of which is close to the junction of the North-British and Caledonian Railways, are all founded on the underlying sandstone, the marls not having been met with at all; and they were absent in the wells at Messrs. Carr's, Caldewgate, and Messrs. Dixon's, West Tower Street; also in that at the Gaol. On the other hand, I saw them in an excavation at the foot of Gaol Brow, on the north side of the Gaol, and have observed traces of them at the bottom of deep drains in Bank Street, Lowther Street, and opposite Cavendish Place in the Warwick Road; but their thickness hereabouts, where they exist, must be very trifling.

West of the Caldew the evidence is much scantier. In addition to the well at Messrs. Carr's, already mentioned, Mr. E. W. Binney records (in the paper before quoted) that at the pumping-engine for the canal by Edenside, immediately above the red and variegated marls, there was a section in the pump-well which distinctly showed the marls at the top gradually passing down into the red sandstone below. Again, at Stainton, on the north side of the Eden, between Carlisle and Grinsdale, a boring showed them to be only 23 feet thick. In the Eden, south of Stainton, the beds are lying nearly flat, except near the North-British railway-bridge, where north-easterly and north-westerly dips occur. There is no evidence as to their thickness near Beaumont.

The above facts, when combined with the great change in direction of the outcrop of the marls between Rickerby and Caldewgate, from about N.N.E. and S.S.W. at the former, to nearly east and west at the latter place, seem to point to their very slight extension below the Lias. Most of the Lias probably rests, therefore, on the Gypseous Shales west of Great Orton, and on the Kirklinton Sandstone east of that village, the Stanwix Marls underlying the Lias only in the neighbourhood of Bellevue.

Fresh borings for coal in the Lias district not being probable, the existence of Rhætic beds is likely to remain an open question. No evidence of them has yet been discovered, all fossils hitherto found having been determined by Mr. Etheridge (our President) to be Lower Lias; but so drift-covered is the country, and so few and small are the sections, that negative evidence must go for very little in settling the question. The Lias country is purely agricultural, and wells sunk for the supply of farm and other houses are usually only from 15 to 20 feet deep, or perhaps half the average thickness of the Glacial drift. Indeed a well-sinker, living near the southern border of the Lias*, informed me, mistaking the motive of my inquiry, that I need not be *afraid* of meeting with any rock below the drift in the locality around his home, as he had sunk at various places he mentioned to depths of 20, 30, or 40 feet without penetrating any thing but sand, gravel, or clay ; for instances in which water, attained on reaching a clayey stratum of drift, has been lost on touching porous sandstone below, have made well-sinkers very careful not to go a single foot lower than is absolutely necessary in the case of ordinary dwellings.

The Lias area has, during the last 250 years, been much explored in search of evidence of coal. It will not seem strange that such has been the case, when it is remembered that the dark shale forming so large a proportion of the rock visible would naturally seem identical with the dark shale of the Coal-measures, and a striking contrast to the red Permian and Triassic beds around. The non-Carboniferous, and probably Liassic, nature of the formation was first discovered by Mr. R. B. Brockbank†, who, on finding Ammonites and other fossils in Thornby Brook, sent them to Mr. E. W. Binney, who pronounced them to be Liassic. Mr. Binney afterwards visited the district and recorded the result in a paper read before this Society‡. I have since discovered but one section not described therein, in a brook between Great Orton and Flat. It is composed of dark shale with limestone bands. *Ammonites Johnstoni* was found there, as also in Thornby Brook and at Quarry Gill, near Aikton. By Mr. R. B. Brockbank's assistance I was enabled to obtain evidence of the thickness attained by the Lias between Great Orton and Flat, a spot nearly at its centre. A document, from which I have already quoted, which has been preserved by the Stordy family of Great Orton, gives the following details, according to a copy of it kindly made for me by Mrs. Hannah Pearson, of Station Hill, Wigton. In the year 1781 a boring was made by John Brisco, of Crofton, in John Stordy's Gill close. A blue stone was found 18 feet from the surface, and "different stone, mostly bluish," till they arrived at a depth of 228 feet. Then they pierced the "red stone or clay, sometimes mixed with veins of white" (which I suppose to be the Gypseous Shales), till they came to a depth of 360 feet.

The Lias area forms a plateau, with a slightly greater general elevation than is attained immediately outside it. This plateau-like character is better marked in the country between Aikton and Great Orton than eastward of the latter place. No person standing about Wiggonby, near the southern border of the Lias, can fail to notice the difference between the flat-topped plateau northward and the rolling drift-ridges to the south. But though this change of feature makes it possible to map the Lias boundaries with some approach to a

* Andrew Miller, Nealhouse.
† Of Moor Park, Crosby, near Maryport.
‡ Quart. Journ. Geol. Soc. vol. xv. p. 549.

fairly good general line, the persistently drift-covered surface prevents any thing like precision.

In conclusion, I will briefly pass in review the leading points bearing on the relations of the beds described to each other, which are illustrated in the diagram sections (figs. 1–3, p. 296).

The St.-Bees Sandstone has been shown to surround the overlying beds, its general dip varying from north to a few degrees north of west, between Maryport and the Eden. In the Hether Burn, Line, and Carwinley Burn its general dip is more or less south of west; and west of the Esk it varies between south-east and south. There can be no doubt that the St.-Bees Sandstone is the lowest bed of a true basin, the western limits of which are now below the Solway.

Then, first of the overlying beds come the Gypseous Shales, which, strange to say, are nowhere exposed to view, but are known on the evidence of the boreholes at Abbey Town and Bowness, and, perhaps I may add, that at Great Orton. Their invisibility is mainly caused by the special thickness and persistence of the drift over the ground they occupy, but also, at Cummersdale, to the probable interposition of a great fault. There is no evidence of any kind suggesting unconformity between the Gypseous Shales and the St.-Bees Sandstone; and, on the other hand, as Gypseous Shales underlie the St.-Bees Sandstone near Carlisle, gypsum is evidently hereabouts a Permian characteristic. I have accordingly classed the Gypseous Shales as Permian.

The Kirklinton Sandstone, however, appears to rest unconformably on the Gypseous Shales to the west, and on St.-Bees Sandstone to the east and north-east of Carlisle. But not only do the Gypseous Shales disappear towards the north-east, but the greater part of the St.-Bees Sandstone is also missing. Six or seven miles south-east of Carlisle the thickness of the St.-Bees Sandstone is estimated by Mr. J. G. Goodchild at from 1500 to 2000 feet; but in the Hether Burn there can hardly be more than 800 feet of Permian rock, from the breccia at its base to the outcrop of the Kirklinton stone below Hether-Bank Bridge; and in Carwinley Burn, between the breccia at the base of the Permian formation and the outcrop of Kirklinton stone at Carwinley Mill, there cannot be more than 250 feet of rock. In both these burns there is an almost continuous series of sections, and there are no signs of faults. Both about Brampton on the one hand and west of the Esk on the other the thickness of the St.-Bees Sandstone must be very much greater. Two outliers of Kirklinton Sandstone exist—one at Canobie, opposite the church, resting on Carboniferous rock; the other on the Cambeck near Walton, resting on St.-Bees Sandstone. Thus the band of St. Bees-like rock seen in the Kirklinton Sandstone on the Line goes for nothing when the whole of the evidence is considered, important as it would be did it stand alone. In consequence of this decided unconformity to the beds below, I have classed the Kirklinton Sandstone as Bunter.

It is evident that the Stanwix Marls, in their turn, repose unconformably on the Kirklinton sandstone; for while at Cliff Bridge and Westlinton they rest upon the lower red beds, at Stainton and

Fig. 1.—*Diagrammatic Section from the Solway, north of Allonby, to near Brampton.*

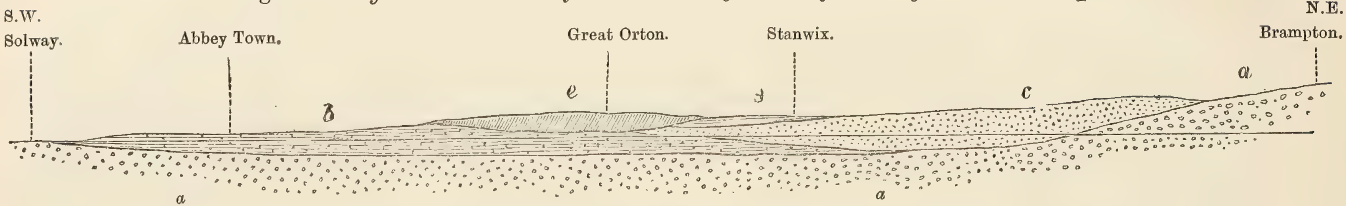


Fig. 2.—*Diagrammatic Section from Solway Moss to Dalston.*

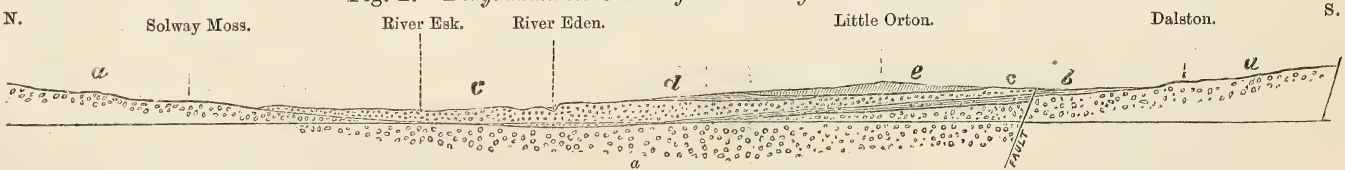
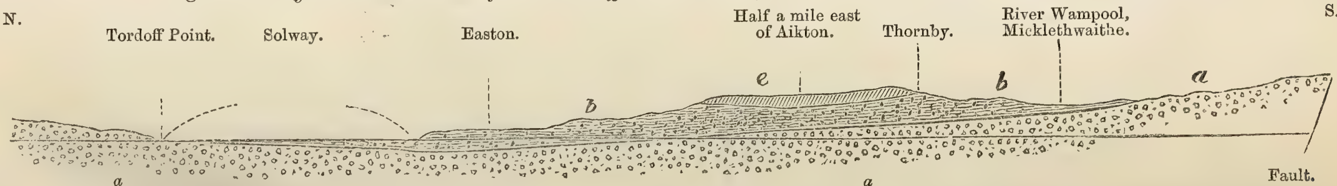


Fig. 3.—*Diagrammatic Section from Tordoff Point, Dumfriesshire, to the Fault south of Wigton.*



a. St.-Bees Sandstone. *b.* Gypseous Shales. *c.* Kirklinton Sandstone. *d.* Stanwix Marls. *e.* Lias.

Grinsdale they lie upon the upper white ones. In consequence of this decided unconformity the Stanwix Marls are here classed as Keuper.

And there seems to me to be little doubt that the Lias, in its turn, rests unconformably on formations all of which are unconformable to each other—the Gypseous Shales, the Kirklinton Sandstone, and the Stanwix Marls. But as in this case it is barely possible, though not, I think, probable, that the Stanwix Marls may overlap the two lower formations and underlie the Lias throughout its area, the possibility seems worth mentioning.

In this paper such facts only have been brought forward as seemed necessary to establish the true relations of the various formations to each other, fuller details being reserved for a forthcoming memoir.

NOTE *on the* LIAS. April 25, 1881.

Since writing my paper, my attention was called by my friend Mr. H. B. Woodward to a passage in a paper by Rev. J. E. Cross "On the Geology of North-west Lincolnshire" (Quart. Journ. Geol. Soc. vol. xxxi. p. 116). Mr. Cross remarks that in the neighbourhood of Appleby he has not been able to detect any Rhætic fossils, though he has searched diligently for them. He says, "the first strata next above the Keuper are those which contain *Ammonites angulatus* and *A. Johnstoni*." He also remarks that *A. angulatus* has the greater range, and extends throughout a zone of 150 feet or more.

In Cumberland *A. Johnstoni* must have a range fully equal to that of *A. angulatus* in North-west Lincolnshire.

In a letter received from Mr. Cross, dated February 22nd, 1881, he states that he has not since detected any Rhætic fossils in the above-mentioned locality, but that, as they may be seen both near Gainsborough on the south and across the Humber on the north, it is very possible that they nevertheless exist there. He also remarks that as "*A. angulatus* is one of the most persistent of Ammonites in its own place, and *A. Johnstoni*, whenever it appears, ranges from the middle of the *A.-angulatus*-beds to strata below those in which *A. angulatus* is ever seen, I think if you find *A. Johnstoni* and do not find *A. angulatus*, you must be below the *A.-angulatus*-beds altogether."

Prof. J. W. Judd, in his paper on "The Secondary Rocks of Scotland" (Quart. Journ. Geol. Soc. vol. xxxiv. p. 697), remarks that the zone of *Avicula contorta* does not appear to be distinctly developed in the West Highlands, while the Infralias (*Planorbis*- and *Angulatus*-zones) attains a thickness of from 150 to 200 feet.

EXPLANATION OF PLATE XI.

Sketch Map showing the rocks of the Carlisle basin: scale 4 miles to 1 inch.

Discussion.

Mr. Bauerman, having experienced the extreme difficulty of understanding the rocks of this district from the obscurity of the evidence, bore testimony to the great care and skill with which the author had worked out such an unpromising subject.

Prof. Judd remarked upon the great interest attachiug to the outlying patch of Lias near Carlisle. The author had now, for the first time, made us acquainted with the thickness of these Lias strata, and proved that it exceeded 200 feet. So far as the evidence went, they belong entirely to the Infralias, and the same member of the Lias was also abnormally thick on the west coast of Scotland. The numerous unconformities pointed out by the author as existing among the red rocks below seemed to show that but little value should be attached to such local unconformities in classifying the strata.

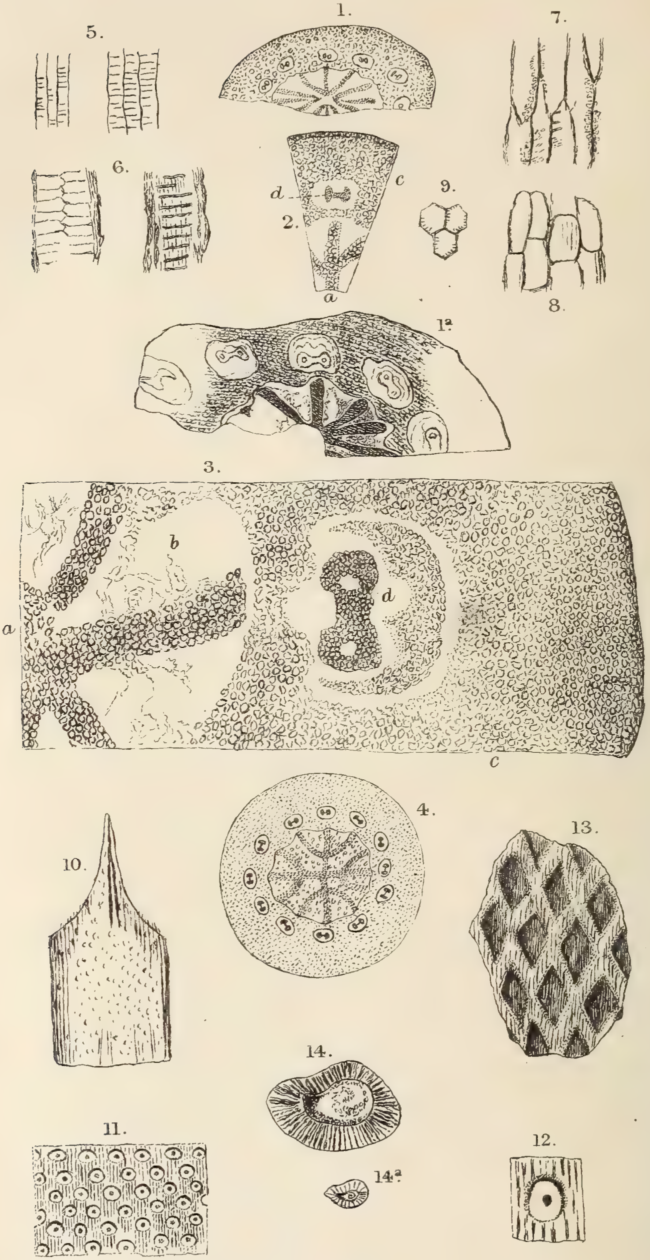
Mr. Whitaker said that his colleague Mr. H. B. Woodward proposed to group the whole of these red rocks under the comprehensive term Poikilitic, and thought that the Rhætic beds are most likely present in the area, although not seen. He spoke of the unsafe character of the colour-test in classifying rocks.

Rev. J. F. Blake asked as to the evidence of the existence of as much as 200 feet of Lias beds belonging entirely to the lowest part of the series, and as to the proofs of the existence of an unconformity between the Stanwix Marls and the Lias.

Prof. T. Rupert Jones protested, with reference to the use of the word "Poikilitic," used by preceding speakers indicative of anti-Permian views, that there had been good grounds for John Phillips and others to determine and establish the Permian Series, and that there were no good grounds for its being again amalgamated with the overlying series.

The President said that no evidence of the occurrence of Rhætic fossils in the area had ever been found, but that possibly the Stanwix Marls might have to be classed with the Rhætic Tea-green Marls of the Bristol area. The Lias of Adderley was let down by means of great faults below the level of the Keuper marls.

The Author said that he advanced his classification as a purely provisional one. He did not think it probable, though it is barely possible, that the Stanwix Marls underlie the Lias. In classing certain of these beds as Permian, Bunter, or Keuper, the author chiefly desired to mark their *relative* positions and affinities, the latter being determined by the existence or non-existence of unconformities between them.



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DEVONIAN PLANTS.

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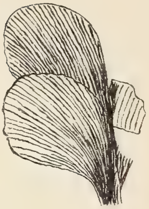

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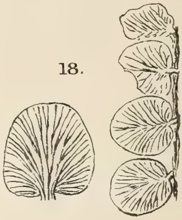

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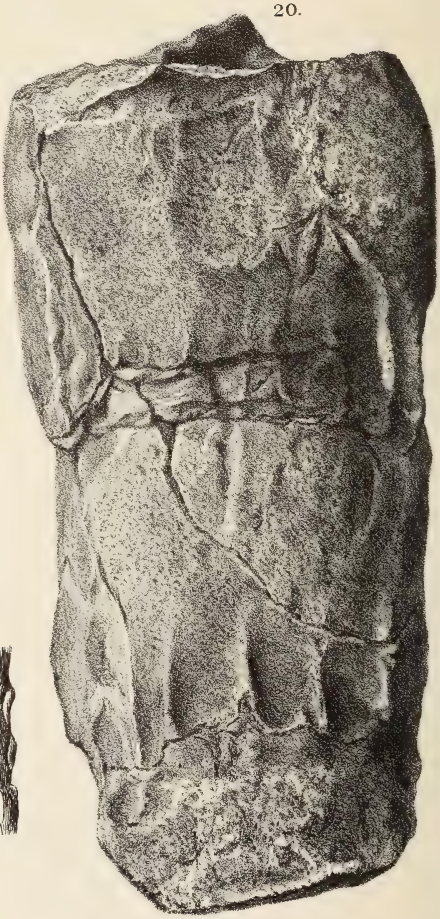

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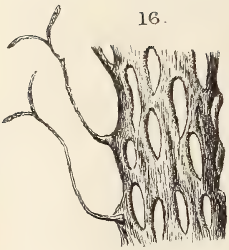

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DEVONIAN PLANTS.

23. Notes *on* New Erian (Devonian) Plants.

By J. W. Dawson, LL.D., F.R.S., F.G.S., Principal of McGill College, Montreal.

(Read June 23, 1880.)

[Plates XII. & XIII.]

The principal purpose of the present paper is to add a few new facts to our knowledge of the Precarboniferous flora of Eastern America. Since the publication, in the Journal of this Society, of my paper, "Further Observations on the Devonian Plants of Maine, Gaspé, and New York" (1863), and that on "Fossil Ferns of the Devonian" (1871), a large addition was made to the knowledge both of the species of plants and of the general character and conditions of Devonian and Upper Silurian vegetation in my "Report on the Devonian and Upper Silurian Plants of Canada"*. In a subsequent report on the "Plants of the Lower Carboniferous and Millstone Grit"†, I endeavoured, by the aid of the American formations, to remove the perplexities that had been caused by the disputes respecting the age of the Kiltorcan beds in Ireland and the so-called "Ursa-stage" of Bear Island, difficulties which, however, still appear to constitute subjects of discussion.

In 1878 I contributed a paper to the Geological Society of Edinburgh, entitled "Notes on Scottish Devonian Plants," comparing these plants with those of America, and at the same time establishing the genus *Ptilophyton*‡ for those remarkable pinnately-leaved Lycopodiaceous plants of which *Lycopodites Vanuxemii* of the Devonian of New York and *L. plumula* of the Lower Carboniferous of Nova Scotia are types, and of which *Pt. Thomsoni* is a Scottish representative described in the paper above referred to.

Since the publication of these reports and papers several interesting new forms have come into my hands from the Devonian or Erian of North America, to which I shall add two new species, one from Scotland and one from Australia, kindly communicated to me by friends in those countries.

Plants from the Erian (Devonian) of New York.

1. Asteropteris noveboracensis, gen. & sp. n. (Pl. XII. figs. 1–9.)

The genus *Asteropteris* is established for stems of Ferns having the axial portion composed of vertical radiating plates of scalariform tissue imbedded in parenchyma, and having the outer cylinder composed of elongated cells traversed by leaf-bundles of the type of those of *Zygopteris*.

* Geol. Survey of Canada, 1871, pp. 100, 20 plates.

† Ibid. 1873, pp. 47, 10 plates.

‡ *Ptilophyton* may perhaps be considered too near to *Psilophyton*, but the sound of the names is quite different. In a recent Report of the Regents of New York, Hall has stated his belief that *Pt. Vanuxemii* is not a plant but a zoophyte. He does not fully state the reasons for this conclusion; but should this view be established with regard to this species, then Göppert's *Lycopodites pennæformis* or my *L. plumula* may serve as the type of the genus.

The only species known to me is represented by a stem 2·5 centimetres in diameter, slightly wrinkled and pitted externally, perhaps by traces of aerial roots which have perished. The transverse section shows in the centre four vertical plates of scalariform or imperfectly reticulated tissue, placed at right angles to each other, and united in the middle of the stem (figs. 1–4). At a short distance from the centre, each of these plates divides into two or three, so as to form an axis of from ten to twelve radiating plates, with remains of cellular tissue filling the angular interspaces (fig. 3, *b*). The greatest diameter of this axis is about 1·5 centimetre. Exterior to the axis the stem consists of elongated cells (fig. 7), with somewhat thick walls, and more dense towards the circumference. The walls of these cells present a curious reticulated appearance, apparently caused by the cracking of the ligneous lining in consequence of contraction in the process of carbonization. Imbedded in this outer cylinder are about twelve vascular bundles (figs. 2, 3, *d*), each with a dumb-bell-shaped bundle of scalariform vessels enclosed in a sheath of thick-walled fibres. Each bundle is opposite to one of the rays of the central axis. The specimen shows about two inches of the length of the stem, and is somewhat bent, apparently by pressure, at one end.

This stem is evidently that of a small tree-fern of a type, so far as known to me, not heretofore described*, and constituting a very complex and symmetrical form of the group of Palæozoic Ferns allied to the genus *Zygopteris* of Schimper. The central axis alone has a curious resemblance to the peculiar stem described by Unger (' Devonian Flora of Thuringia') under the name of *Cladoxylon mirabile*; and it is just possible that this latter stem may be the axis of some allied plant. The large aerial roots of some modern tree-ferns of the genus *Angiopteris* have, however, an analogous radiating structure.

The specimen is from the collection of Berlin H. Wright, Esq., of Penn Yan, New York, and was found in the Portage group (Upper Erian) of Milo, New York, where it was associated with large petioles of ferns and trunks of *Lepidodendra*, probably *L. chemungense* and *L. primævum*.

In previous communications to the Society I have described three species of tree-ferns from the Upper and Lower Devonian of New York and Ohio ; and this species is from an intermediate horizon. All four occur in marine beds, and were, no doubt, drift-trunks from the fern-clad islands of the Devonian sea. The occurrence of these stems in marine beds has recently been illustrated by the observation of Prof. A. Agassiz, that considerable quantities of vegetable matter can be dredged from great depths in the sea on the leeward side of the Caribbean Islands. The occurrence of these trunks further connects itself with the great abundance of large petioles (*Rhachiopteris*) in the same beds, while the rarity of well-preserved fronds is explained by the coarseness of the beds and also by the probably long maceration of the plant-remains in the sea-water.

* Prof. Williamson, to whom I have sent a tracing of the structure, agrees with me that it is new.

2. EQUISETIDES WRIGHTIANA, sp. n. (Pl. XII. fig. 10 & Pl. XIII. fig. 20.)

This is a specimen in the same collection with the above. It is a cast in sandstone, 6 centimetres in diameter, with nodes from 4 to 5 centimetres apart. The surface has a slight carbonaceous coating and is finely tuberculated, the tubercles being very regularly arranged, and representing the bases of very short hairs or bristles, which are seen entering the surrounding matrix. Impressions above the joints appear to indicate sheaths, each of about twelve broad leaves, which are abruptly narrowed and acuminate at the top, and show an indication of a median nerve or rib (fig. 10). The leaves of the sheaths are 1 centimetre broad and 1·7 centimetre long. It would be possible, however, to interpret these supposed sheaths as due to mere plications or foldings of the epidermis; and in this case the plant may have borne verticils of leaves, of which these supposed sheaths may be merely the remains. The first explanation, however, appears more probable; and, if it is correct, the plant is a true *Equisetides*, and the present specimen is the first occurrence of this genus in beds older than the Carboniferous. It is to be observed, however, that Unger has described from the *Cypridina*-slates of Thuringia plants of the genera *Kalymma* and *Asterophyllites* (*A. coronata*) with sheaths at the nodes; and my *A. scutigera*, from St. John's, has verticils of scales at the joints, which may represent sheaths. The present species has a remarkable resemblance in its markings and the form of its sheaths to a greatly magnified stem of the modern *Equisetum fluviatile*, except that the leaves of the sheaths are shorter.

The species is named in honour of its discoverer. Its essential characters will be as follows:—

Stem stout, cylindrical or broadly ribbed, surface marked with short hairs or tubercles regularly arranged. Sheaths at the joints, of about twelve leaves, of the general form of those of *Equisetum fluviatile*.

The specimen is from the Portage group (Upper Erian) of Italy, New York.

3. CYCLOSTIGMA AFFINE, sp. n. (Pl. XII. figs. 11 & 12.)

Stem marked with alternate circular leaf-bases or areoles, slightly prominent below, evanescent above, and each with a circular dot or vascular mark. Scars scarcely two millimetres in diameter, and separated by finely corrugated bark, about twice their diameter apart. These markings occur on a stem about an inch in diameter. The *Knorria*, or decorticated form of this plant, presents irregular waving ridges, produced by the longitudinal confluence of the oblique vascular bundles.

This plant is the nearest approach to the well-known *C. kiltorkense* of Ireland hitherto found in America. It differs chiefly in the more closely placed areoles. It was collected by Mr. Wright, and is from the Chemung (Upper Erian) of Italy, New York. The study of this plant has led me to the belief that *Stigmaria exigua* of my Report of 1871 may, when better known, prove to be a new species, allied to the present, and a member of the genus *Cyclostigma*.

4. Lepidodendron primævum, Rogers. (Pl. XII. fig. 13.)

Mr. Wright's collection contains fragments of a *Lepidodendron* from Milo, New York, which seems to belong to the species above named, but presents the curious peculiarity of having the leaf-bases depressed instead of being prominent. This may result either from some peculiarity of pressure or from the leaf-bases being deciduous and leaving depressed scars when removed. In either case these specimens illustrate this peculiarity as seen in the Lower Silurian *Glyptodendron* of Claypole, which may possibly have had decorticated leaf-bases. Specimens of this kind, of course, retain no distinct vascular marks, and the impression on the matrix resembles those decorticated *Lepidodendra* of the Coal-formation which used to be named *Lyginodendron*, but which, in Nova Scotia at least, usually belong to the species *Lepidodendron rimosum.*

5. Celluloxylon primævum, gen. & sp. n.

A silicified trunk, showing in cross section large and somewhat unequal hexagonal cells, with an appearance of lines of growth caused by concentric bands of smaller cells. No medullary rays. The longitudinal section shows either cells superimposed in vertical rows, or a sort of banded prosenchymatous tissue; but the structure is much masked by the crystallization of the quartz.

This specimen is from the collection of Prof. J. M. Clarke, of Amherst, Massachusetts, and was obtained from the Hamilton (Middle Erian) of Canandargua, New York. It was undoubtedly a woody stem and not an Alga; but its structure is even less specialized than that of *Prototaxites*, from which it differs in the want of medullary rays, and in its less distinctly elongated wood-cells without spiral markings. It has some resemblance to *Aphyllum paradoxum* of Unger, but is more uniform in its structure. It adds another to those mysterious woody stems of doubtful affinities which, in the Devonian or Erian of both sides of the Atlantic, represent the Taxineæ and Conifers of later formations.

Additional specimens received from Prof. Clarke show that the appearance of rings of growth is caused by large cells disposed in concentric narrow bands between the wider bands of fine fibrous tissue. In the longitudinal section these bands of large cells appear to be parenchymatous and not vascular. There are no medullary rays, but rounded patches of cellular tissue appear here and there in the fibrous layers. The structure is thus very peculiar, and appears to have been the result of a kind of exogenous growth, in which coarse parenchymatous layers were deposited between the periodical rings of the stem, reminding one of the bark-like layers interposed between the growth-rings in *Gnetum* and in some tropical climbers. The stem of the present plant was, however, in all probability, of much more simple character, though woody and capable of resisting pressure. It is to be observed also that the specimens neither show the structure of the pith or bark, and that the finer structures of the tissues preserved must have been partially obliterated by the granular crystallization of the quartz with which the specimen is mineralized.

Miscellaneous Specimens from New York.

Numerous large petioles of Ferns occur in collections sent to me by Mr. Wright and Dr. Parker of Ithaca, New York. Being destitute of the fronds, it seems unnecessary to describe them more particularly; but they indicate the possibility that the Erian of New York may yet afford a rich Fern-flora comparable with that of St. John, New Brunswick. In collections made by Mr. Wright are also specimens of those singular plants, supposed to be Algæ, which Hall has named *Dictyophyton.* A very fine specimen of one of the species was figured in my paper of 1863, under the name *Uphantænia chemungensis*, originally bestowed on one of the species by Vanuxem, but which is rejected by Hall in favour of the generic name above given. The specimens sent by Mr. Wright do not give any additional information as to the mode of growth of these curious forms; but he has found in the Hamilton formation, not previously known to contain these plants, a species probably distinct from those described by Hall, and which may be named *D. hamiltonense*; though if these plants were really Algæ, the supposed species may be nothing more than varietal forms or stages of growth.

The specimens referred to are unequally turbinate or unequally conical in form, rapidly expanding from the base, and marked with sharp longitudinal ridges, crossed with much finer and more frequent revolving lines. The largest specimen is almost 1½ inch in diameter, narrowing to less than 1 inch in a length of less than 2 inches.

The remarkable spiral plant belonging to the genus *Spirophyton* of Hall, the "*Cauda-galli* fucoid" of the earlier Reports on the State of New York, is found in the same beds with *Dictyophyton.* It is also found, as mentioned in my paper of 1863, in Gaspé, where it ranges from the Upper Silurian into the Lower Devonian. Plants of the same genus have been found by the late Prof. Hartt on the Rio Tapajos, in Brazil, in beds referred to the Carboniferous period, though some other plants found in the same beds might in North America be supposed to be Upper Devonian in age. In MS. descriptions of these plants sent to Prof. Hartt, and which may have been published in his Reports, I named this species *S. brasiliense.* It is of interest as showing the very wide distribution of this form in the palæozoic seas.

Plants from the Erian (Devonian) of St. John, New Brunswick.

I have recently obtained, from the widow of the late lamented Prof. Hartt, the remainder of his Devonian plant-collections, consisting principally of duplicates of the more common species found at St. John, but with a few fragments indicating forms not previously known to me.

Since the publication of my papers and reports on the fossils of the St.-John beds, they have been repeatedly referred to by European palæobotanists as Lower Carboniferous, apparently on no better grounds than their superior richness in plants to the Devonian of Europe. On this account it may be desirable here to summarize the evidence now available as to their actual age. This may be stated thus:—(1) The *Dadoxylon* Sandstone and Cordaite shale of Southern New Brunswick are folded up and partially altered with the Silurian and Cambrian rocks of the district, and are overlain unconformably by the Lower Carboniferous conglomerates (Subcarboniferous of some American geologists). These conglomerates are, further eastward, associated with beds holding the characteristic fossil plants of my Horton series, equivalent to the Tuedian or Calciferous series of Scotland. There is also evidence that the Devonian plant-beds are anterior to the great intrusive Devonian granite of this region, whose débris are found in the Lower Carboniferous conglomerates, but not in the underlying rocks. Additional facts illustrative of these points will be found in the Reports of Messrs. Bailey and Matthew in the publications of the Geological Survey of Canada for 1871 and 1875.

(2) The flora of these beds is markedly different from that of the Lower Carboniferous, of the Millstone Grit, and of the true Coal-formation in New Brunswick and Nova Scotia, all of which have been studied and described.

(3) The prevalent forms in the St.-John beds are those characteristic of the Devonian in Gaspé, New York, and Maine, such as *Archæopteris*, *Cyclopteris obtusa*, *Psilophyton*, *Calamites radiatus*, *Dadoxylon ouangondianum*, though several genera are common to these beds and the Carboniferous. The fact that the flora of these beds is richer than that of the European Devonian, and contains types which appear later in Europe, is in harmony with known facts as to the earlier appearance of plants in America in other stages of geological history. I may add that some of the genera noticed in 1863 from St. John, and not then known in the Devonian of Europe, have subsequently been found there. Even as late as 1879 some of them were discovered by Peach in the Old Red of Scotland.

(4) The new facts which have been disclosed, more especially those which indicate the great richness of the Devonian flora of New York in Ferns, now induce me to believe that these St.-John beds, though rivalling the Coal-formation in their abundance of fossil plants, are really of the age of the Hamilton group of New York, which in Europe would be regarded as Middle Devonian.

(5) I would further add that the richness of this flora in species, as well as the discovery of rare and exceptional forms, such as insects, is in part due to the excellent exposure of the beds in the vicinity of St. John, and in part to the extensive and thorough nature of the explorations carried on with the aid of blasting by Messrs. Hartt and Matthew, under the auspices of the Natural-History Society of New Brunswick. It is probable that few fossiliferous beds in the world have been so thoroughly explored. In connexion with this it is to be observed that the mass of the specimens obtained represents only a few species, while the greater number are represented

by only a few fragments, which would undoubtedly have escaped the observation of ordinary collectors.

In the collections now in my hands the following forms occur, which may be considered new, though most of them are too imperfect for complete description.

Odontopteris squamosa, sp. n. (Pl. XIII. fig. 17.)

Petiole slender, bearing short pinnules placed at right angles to it, and each consisting of two rounded decurrent pinnulæ and a terminal pinnule of triangular form. Toward the end only the terminal pinnule appears. Veins obscure, diverging from a midrib, broad at base. Frond apparently of a thick or coriaceous texture.

This would seem to have been a creeping or parasitic Fern. In its general habit it bears some resemblance to *Cyclopteris dissecta* of Unger, from the Devonian of Thuringia, but appears to have more affinity with the genus *Odontopteris* than with *Cyclopteris*.

Cardiopteris eriana, sp. n. (Pl. XIII. fig. 18.)

Pinnules nearly round or slightly oblong, nearly equally cordate at base, somewhat crowded on a slender petiole. Length from 8 to 14 millim. Veins regularly spreading from the centre of the base, curving toward the margin, and forking twice or thrice.

This is the first appearance of this Lower Carboniferous genus in the Devonian. The species closely resembles *Cyclopteris polymorpha* of Göppert, though every way smaller and more delicate.

Archæopteris ?, sp. n. (Pl. XIII. fig. 19.)

Petiole apparently woody, bearing broadly obovate decurrent pinnules, with strong, flabellate, straightish nerves. Pinnules overlapping each other.

This plant bears a general resemblance to *Archæopteris* of the type of *A.* (*Cyclopteris*) *Maccoyana* of Göppert; but the woody petiole or branchlet, and the coarse texture of the pinnules, raise the suspicion that the specimen may not be a Fern, but may have belonged to a coniferous tree of the type of *Voltzia* or *Salisburya*.

Cyclopteris, sp.

Fragments of a very large cyclopterid leaf, with flabellate veins, and which, when entire, must have been three inches in diameter. It is too imperfect for description, but indicates a frond of the same general character with *Cyclopteris Brownii* from Peny, in Maine.

Other specimens indicate a small species of *Archæopteris*, more delicate than *A. Jacksoni*; and there are some fragments which seem to show, though not indisputably, that the submerged leaves of *Asterophyllites latifolia* were long and linear, approaching in form to those previously described as *A. lenta*. A fragment of *Hymenophyllites*, about the size and form of *H. Gersdorffii*, shows minute rounded spore-cases comparable with those of the modern genus *Todea*, which the Fern itself also closely resembles.

The species above described add to the number of small and delicate Ferns by which the St.-John beds are so especially characterized.

Specimens from Scotland and Australia.

Ætheotesta devonica, sp. n. (Pl. XII. figs. 14, 14*a*.)

Fruit 4 millim. in diameter, oval in cross section. Testa less than 1 millim. in thickness, and consisting of radiating fibres. Nucleus represented by white mineral matter with coaly specks. The specimen shows only a cross section; but there seems no reason to doubt that it is the seed of the above genus of C. Brongniart*, hitherto found only in the Coal-formation of France. It may be referred to *Taxineæ*, and may have been the seed of trees of the genus *Dadoxylon*.

The specimen is in grey sandstone, associated with fragments of carbonized plants. It was collected by the Rev. Thomas Bodun, of Edinburgh, in the Old Red Sandstone of Perthshire, where it is associated with *Lycopodites Milleri* and *Psilophyta*.

Dicranophyllum australicum, sp. n. (Pl. XIII. figs. 15 & 16.)

Stem slender, 3 millim. in diameter, not tapering in a length of 3 inches. It is marked with minute, narrow, elongated leaf-bases, spirally arranged. Leaves linear, 3 millim. long, bifurcating at an obtuse angle at their extremities.

The specimen is in white sandstone and is well preserved. It was collected by Mr. R. L. Jack, F.G.S., of the Geological Survey of Queensland, in sandstones associated with limestone, on Fanning River, Burdekin, Queensland. The horizon is said to be under the Mt.-Wyatt and Star beds, and consequently lower than that of the plants collected by Mr. Daintree, and described by Mr. Carruthers in the Journal of this Society.

The genus *Dicranophyllum* was established by Grand'Eury† for certain plants of the French Coal-fields, which, though larger and better-developed than the present species, must have been somewhat similar. Grand'Eury regards these plants as probably Coniferous.

The plants described in this paper are fragmentary and imperfect, but they add six or seven types to the Erian flora, and encourage the hope that all the Carboniferous genera may yet be recognized in the older formation, together with others peculiar to itself, thus tending to vindicate the opinion expressed in a former paper that the plant-life of the Devonian was more varied or less monotonous than that of the Coal-formation.

Supplementary Note.

As some delay has occurred in the publication of the above paper, I may be permitted to add the following:—

(1) In my paper on Devonian Tree-ferns in the 'Quarterly

* Annales des Sciences Naturelles, vol. xx. † Flore Carbonifère.

Journal' of this Society for 1871, I referred, under the names of *Psaronius textilis* and *Caulopteris Lockwoodi*, to certain remarkable trunks of Ferns from the Chemung formation (Upper Devonian) of Gilboa, New York, placed in my hands by Prof. Hall and Mr. Lockwood, and which were stated to be from a locality where numerous erect trees exist. Prof. Hall has since extracted several of the largest of these trees, and they are now in the State Geological Collection at Albany, where I lately had the pleasure of examining them. They entirely confirm my conclusions as to their nature, derived from the fragments submitted to me, being evidently trunks of large tree-ferns surrounded by masses of aerial roots, in some cases 2 feet in diameter at the base, and apparently passing downward into a shaly bed or underclay filled with rootlets. Prof. Hall hopes shortly to publish illustrations of these remarkable trunks, representing the oldest fossil forest yet known.

(2) In the course of last summer, the researches of Messrs. Ellis, Foord, and Weston, of the Geological Survey of Canada, have disclosed, near the head of the Bay de Chaleurs, some interesting exposures of Devonian beds rising from beneath the Lower Carboniferous (Bonaventure formation of Logan). In some of these beds, probably Middle Erian, there are abundant remains of *Psilophyton*, similar to those of Gaspé Bay; but others, which are evidently upper members of the Erian system, contain fossil fishes referred by Mr. Whiteaves to the genera *Pterichthys*, *Tristichopterus*, *Phaneropleuron*, and *Cheirolepis*. In the same beds with these fishes occur fronds of three species of Ferns, of which I have myself collected specimens in a visit to the locality in July last, though the best examples have been found by Mr. Foord. One of the species is an *Archæopteris*, allied to *A. hibernica* and *A. Jacksoni*, but differing in the details of the fructification, which is well preserved (*A. magnacensis* *, MS.). Another is a magnificent fern, referable in the meantime to the provisional genus *Cyclopteris*, and identical with that figured by Lesquereux in the Report of the Geological Survey of Pennsylvania (new series) as *Archæopteris obtusa*. Lesquereux's specimen is from the Chemung or Catskill of Montrose, Pennsylvania. A third species is that described by me, in Quart. Journ. Geol. Soc. vols. xviii. & xix., as *Cyclopteris Brounii*. In the specimens from Bay de Chaleurs the large flabellate fronds of this fern are seen to be attached in dense groups to a rhizome or slender stem, showing that this plant was either, as I supposed in regard to the specimens which I described from Peny, in Maine, a low-growing ground-fern or an epiphyte.

(3) In the "discussion" of my paper I observe a statement to the effect that *Asteropteris noveboracensis* may be a lycopodiaceous plant. In reply, I think it sufficient to refer to the description and figure, but may add that I have had occasion in previous papers to refer to the remarkable abundance and variety of ferns in the islands of the Devonian sea. In accordance with this, the beds near Milo, New York, in which *Asteropteris* occurs, abound in stipes of large ferns,

* Cape Magnach is the locality.

while the only lycopodiaceous plant which they have afforded is *Lepidodendron primævum.*

DESCRIPTION OF THE PLATES.

Plate XII.

Figs. 1, 1*a*. *Asteropteris noveboracensis*, cross section, natural size and enlarged.
2. *A. noveboracensis*, portion enlarged, showing one vascular bundle.
3. —— ——, portion enlarged 12 times, showing rays and vascular bundle.
4. —— ——, stem restored in cross section.
5, 6. —— ——, scalariform vessels, × 100.
7. —— ——, prosenchyma of outer cylinder, × 40.
8, 9. —— ——, parenchyma of inner cylinder, × 40.

In the above figures, *a* represents radii of axis, *b* cellular tissue of axis, *c* outer prosenchyma, *d* leaf-bundles.

10. *Equisetides Wrightiana*, leaf of sheath.
11. *Cyclostigma affine.*
12. —— ——, leaf-base, enlarged.
13. *Lepidodendron primævum.*
14. *Ætheotesta devonica*, natural size and enlarged.

Plate XIII.

15. *Dicranophyllum australicum.*
16. —— ——, enlarged.
17. *Odontopteris squamosa.*
18. *Cardiopteris eriana.*
19. *Archæopteris*, sp. n.
20. *Equisetides Wrightiana.*

Discussion.

Mr. Carruthers spoke very highly of the industry of Dr. Dawson in collecting fossils, but he could not agree with him in his conclusions as to their systematic relations. He thought the form described as a fern should be referred to the Lepidodendroids.

24. *On* Fossil Chilostomatous Bryozoa *from* South-west Victoria, Australia. By Arthur W. Waters, Esq., F.G.S. (Read April 25, 1881.)

[Plates XIV.–XVIII.]

Part of the material forming the subject of the present communication I received in exchange from Miss E. C. Jelly, in a small test-tube, already washed out of the clay; and on two subsequent occasions she has kindly lent me a number of slides from her collection. The "lump of clay" out of which they were washed was sent over to England marked "Yarra-Yarra, Victoria," by Mr. John Allen some years ago; but the exact locality Miss Jelly has been unable to obtain for me. However, I find that Mr. H. Watts, in a paper "On fossil Polyzoa" (in the Trans. Roy. Soc. Vict. vi. 1865, p. 82–84), mentions a deposit from which Mr. Allen sent fossils, and says, "The deposit is described as being about thirty miles east of Warrnamboul, extending along the sea-coast for a distance of from six to seven miles, and is from thirty to forty feet in thickness." A letter I wrote to Mr. Watts, on the possibility of its finding him, has elicited no response; and I therefore presume that he must be dead or have removed, and fear that the exact locality will not now be discovered.

From the memoirs of the Geological surveys I conclude that it will be found to be what the Australian geologists call Miocene, though as yet this has not been shown to be of the age of the European Miocene formation. Mr. Etheridge, Jun., writes that Allen prospected in the "quartz cement which was considered by McCoy of Pliocene age," and says "the country traversed by Allen and party also consisted, especially near the coast, of beds which were referred by McCoy to the Miocene period." Mr. Etheridge, Jun., thinks probably the material marked Yarra-Yarra came from these beds, and there is reason for supposing that the material was not quite correctly labelled. The fossils which have been found in Muddy Creek, Hamilton, Victoria, seem to support the Miocene age of the beds; and similar Miocene clays, according to the Survey, occur in several places, as near the mouth of the Aire river and also near Geelong.

Besides the Bryozoa, I found a large series of Foraminifera very well preserved; and I spent much time in picking out a large number, probably representing 50–100 species, which I forwarded to Professor Karrer of Vienna, from whom I hear that he hopes to complete the examination of the series this spring; and I anticipate that they will throw some light on the age of the formation, as the Foraminifera, both fossil and recent, have had much more attention than the Bryozoa. There were also a number of long slender *Isis*-joints, which I submitted to one of our authorities without any result. The few molluscan shells are probably fry, and do not give much assistance, but support the "Miocene" age of the beds. There are also a few Entomostraca.

The fragments of Bryozoa are small; but their state of preservation is often very perfect; and in this lies their chief value. Their examination may well be used as an introduction to the study of the Mount-Gambier series of Australia, in which, so far as I am able to judge from the London Geological Society's collection, kindly lent to me, and from a collection belonging to Mr. Etheridge, jun., also in my hands, the state of preservation often does not admit of the details being seen; so that the determination and description of these is sometimes very unsatisfactory if other material is not at hand to be used as a key to the structure. As examples I may mention *Microporella yarraensis*, *M. violacea*, var., *Porina clypeata*, and *Retepora rimata*, which occur in the Mount-Gambier beds; but the details are wanting, and were it not for the "Yarra-Yarra" specimens I should have been unable to classify them.

The living British Bryozoa have recently been reclassified by Mr. Hincks, who has introduced in some sections an almost new classification. Since the appearance of his work no palæontogical papers of any importance have appeared; and it therefore becomes necessary to consider how far this classification is applicable in the determination of fossils; and it is here that we shall perhaps find the weak point in the modern classification: but, on the other hand, fossils more than recent forms show the utter unnaturalness of the older divisions. Although generic determination will often be difficult, that is by no means confined to the present system; for we often find fragments showing many important characters without being able to distinguish if they have grown in the *Eschara* or *Lepralia* form. Every change of classification should, of course, aim at making the system more natural; but at the same time special attention should be given to those characters which can be distinguished in fossils, seeing that the number of known fossil forms is so many times more than all the known recent ones, and ultimately the relationship of the living ones must be worked out largely by means of the palæontological record.

In the classification used by Busk in his 'Crag Polyzoa,' and, with some modifications, by Reuss, the form of the colonial growth was made the first consideration; so that colonies of cells of a certain form incrusting stones or seaweed were called *Lepralia*, while quite similar cells, growing back to back, forming an erect coral-like stem, would be called *Eschara* or, if there was only one layer, *Hemeschara*. With more careful examination and comparison of recent and fossil forms this was found to be an absolutely untenable position, as the same forms of cells so frequently occur that any one well acquainted with recent and fossil Bryozoa could in a short time draw up a list of at least 40 or 50 cases where absolutely identical cells are known in the *Lepralia* and *Eschara* forms. Smitt *, recog-

* Krit. Fört. öfver Skandinaviens Hafs-Bryozoerne, af F. A. Smitt. Öfv. Vet. Ak. Förhandl. 1864–1868.

nizing this, based his classification mostly upon the form of the oral aperture; and Mr. Hincks has followed Smitt's example, introducing some modifications. But sometimes there is a peristome obscuring the oral aperture; so that it is difficult even in recent species to see the shape of the real aperture, unless there is sufficient material at hand to make the necessary preparations. As an example, in *Tubucellaria cereoides*, Ell. & Sol., the operculum which closes the primary aperture is situated at some distance from the end of the peristome, which is produced into a long tube. In fossils, however, it is sometimes impossible to make out the exact form of the opercular aperture, even when other details are extremely well preserved; for an example of which I only need refer to *Porina clypeata* (Pl. XVI. fig. 67), in which the details are so well preserved that I think there is no doubt it can be easily recognized when found elsewhere.

Probably no naturalist at all thoroughly acquainted with the Bryozoa will again attempt to sustain such genera as the old *Lepralia* and *Eschara*; but it may be well to examine carefully the growth of the Bryozoa before we entirely reject the form of the colony as of classificatory value; for in many cases it may be shown in this way from which part of a zoœcium the following zoœcium grows. The mode of growth of *Lepralia* and *Eschara* indicated no structural difference; for the young zoœcia in both grew out from the same part of the parent cells, and *Eschara* was only formed of *Lepralia*-cells back to back, often very slightly attached. For an example of the new zoœcia arising in a different manner we may cite *Bicellaria* and *Bugula*, and fig. 33, provisionally placed with *Cribrillina* as *C. dentipora*. The form of the aperture must be the first consideration; but especially among fossils we must carefully notice how they grow; and it is to be hoped that this latter question may soon receive a thorough and conscientious investigation, as it is a point requiring still further elucidation. At one time I hoped to be able to devote some time to this question, which must be a laborious one; but I fear the state of my health will not allow me to carry it out.

If the principles of the old classification had been adopted, it would have been necessary to make several new genera; but workers on recent Bryozoa have already overthrown the classification based upon the zoarial form, and therefore palæontologists should follow Smitt, Hincks, and others, and describe their species in such a manner, and use such a nomenclature, that fossils can be compared with living species.

The Australian Bryozoa, both recent and fossil, have been as yet very imperfectly worked out. The most important works concerning living forms are Macgillivray's* papers, and, for the Catenicellidæ, that of Prof. Wyville Thomson†. Prof Hutton has drawn up a list

* MacGillivray, P. H., "Notes on the Cheilostomatous Polyzoa of Victoria," Trans. Roy. Soc. Vict. pt. ii. vol. iv. 1860; id. "Descr. of some new Genera and Species of Australian Polyzoa," *loc. cit.* vol. ix. 1869; id. in 'Prodromus of Zoology of Victoria,' edited by F. M'Coy, decades iii. & iv. 1879.

† Wyville Thomson, "On new Genera and Species of Polyzoa," Zool. Bot. Assoc. Dublin, vol. i. 1859.

of the New-Zealand fauna; but, as he does not seem to have devoted himself much to the Bryozoa, we cannot make comparison with the New-Zealand species until some specialist has worked at them *. There are several species described by Busk and Hincks in their papers and works; and lately the study has been taken up by Haswell, Goldstein, Maplestone, and J. B. Wilson, with interesting results.

The fossils have attracted comparatively very little attention. In 1859 the Council of this Society admitted a Note † by Mr. Busk on Mount-Gambier fossils; but this only consisted of a list of 37 species, 32 of which were new and were not described, but only christened; so that it still remains perfectly useless for comparison. These names have sometimes been quoted; and workers have wasted their time in libraries searching for the descriptions; and in the various bibliographical and specific lists published by Mr. Etheridge, Jun., these names are all referred to in full, and thus some pages are filled up with empty names. As Stoliczka points out, such anticipatory publication brings confusion without equivalent advantage; and certainly in this case there has been much irritation and ink wasted, which might have been avoided if the paper had been entirely ignored. In Mr. J. E. T. Woods's "Geol. Observations in Australia" entirely unsatisfactory figures without description appeared; and since then Mr. Woods has published a few short papers, to which I refer in the descriptive text, of which I will only mention his paper "On some Tertiary Australian Polyzoa" and "Australian Selenariadæ," in which fossils from Mount Gambier and Muddy Creek, Hamilton, Victoria, are described, both being considered of the same age. Therefore we may say that, with the exception of the papers by Mr. Woods and one shortly to be mentioned by Mr. Wilson, no work has been done on the Australian fossil Bryozoa; but in the description of the Novara Expedition, vol. i. pt. 2, an important paper is published by Stoliczka ‡ on the Bryozoa from the marine beds of the Waitemata Schichten of Orakei Bay, New Zealand; and as eight species are common to both formations, the two deposits are of somewhat the same age.

At the time I commenced the study of this material no fossil Catenicellidæ were known; but since mine were lithographed, Mr. J. Bracebridge Wilson § has described and designated by numbers twelve species, with none of which am I able to identify any of my species. But the characters on which *Catenicellæ* must be grouped are as yet scarcely understood; and much change must be made in the classification, as undoubtedly some of the names now in common

* F. W. Hutton, Catal. of Marine Mollusca of New Zealand, Wellington, 1873; id. "Corrections and Additions to the List of Polyzoa in the Catal. of Marine Mollusca of N. Zeal.," Trans. New-Zealand Inst. vol. ix. 1876.

† "Note on the Fossil Polyzoa collected by the Rev. J. E. Woods near Mount Gambier, South Australia," by George Busk, F.R.S., F.G.S., &c., Quart. Journ. Geol. Soc. vol. xvi. 1860, p. 260.

‡ Fossile Bryozoen aus dem tert. Grünsandstein der Orakei Bay bei Auckland, von Dr. Ferd. Stoliczka, 1864.

§ "Fossil Catenicellæ from the Miocene beds at Bird Rock, near Geelong," Journ. Micr. Soc. Victoria, vol. i. nos. 2, 3, p. 60.

use are synonyms. As with other Bryozoa, so in *Catenicella*, the form of the aperture will have to be considered of primary importance. This Mr. Wilson does not seem to have appreciated; for only in one case does he mention the shape of the aperture, and, while in some the shape may not be distinguishable, we can hardly suppose that all the twelve are so badly preserved as to have this principal character destroyed. I have recently found two species of *Catenicella* in the Geological Society's collection from Mount Gambier. It is therefore not impossible that when the figures which Mr. Wilson promises are published, one or two may be found to occur near Geelong and in the present locality.

One most extremely interesting form—indeed, the most interesting specimen in the collection—is *Catenicella internodia* (fig. 78), consisting of long internodes with a double row of cells, whereas all the Catenicellidæ now living have short beaded internodes, consisting of one, two, or even three cells; and we may find that forms with one or two cells in a node have developed from multicellular nodes, and should then ask, have not all jointed forms adapted themselves from unjointed ones? This and the Mount-Gambier collections furnish unjointed *Crisiœ*. In the living fauna of Australia the number of jointed forms is very remarkable; but already in the European Chalk the number was very considerable.

The Microporellidæ are well represented, and also show that the genus *Microporella* must be extended; for we are able to trace relationship from *M. violacea*, with a round pore, to the var. *fissa*, with an elongate pore (fig. 73); then we have *M. yarraensis*, with two or three denticulated pores in the depression; and in this way pass on by *M. coscinopora* and var. *armata*, to *M. symmetrica* (fig. 83). This group, with an area with several large pores, was well represented in the Eocene and Miocene of Europe by *M. coscinopora* &c.; and perhaps as the recent forms are further studied we shall find several living allies; for *Microporella* (*Eschara*) *distoma*, Busk, from Madeira and, in my collection, from Capri, from 150 metres, must evidently be looked upon as related; and I find in my specimens from Capri that the pores are stelliform, which seems to be a frequent if not general character in the group, and is of great interest, as showing a correlation of characters, and supports the opinion of those who believe that we are now on the track towards a more natural classification. From the above remarks it will be judged that *Porellina*, Sm., which is separated from the other Microporellidæ in consequence of having the pore in a lunate form, is not considered a necessary genus.

If the comparison is extended a little further we may find that such a form as *M. symmetrica* (fig. 83) is related to the Cribrillinidæ through such forms as *C. terminata* (fig. 68).

In studying both recent and fossil forms I have often been impressed with the frequency with which open pores are replaced by avicularia, and think that it is a matter worthy of most careful examination; and, considering that there is reason to believe that avicularia may be only differentiated pores, I enter into the question when speaking of *Cribrillina suggerens*.

The number of species of Chilostomata mentioned in this paper is seventy-two; and, so far as my preliminary examination goes, it seems that there are about thirty determinable species of Cyclostomata; so that from this one small lump of clay there cannot be less than two hundred determinable species when we add together the Bryozoa, Foraminifera, Entomostraca, and other remains. It now becomes necessary to make comparison of these Chilostomata with those found in other strata; and we find that a large proportion are identical with those from the Orakei-Bay beds in New Zealand. Stoliczka's descriptions and figures do not in all cases permit of comparison; but out of a total of twenty-nine comparable species, there are from Yarra-Yarra seven Chilostomata and seven Cyclostomata. With the Mount-Gambier beds the number is large; but this is the result of direct comparison, whereas I have had no opportunity of seeing any fossils from Orakei Bay; and the number of species from Mount Gambier, known to me, and of which I hope shortly to publish a list, is greater than the Orakei-Bay list. The number of identical species from the two places is now twenty-three Chilostomata; but as I progress with the determination of the Mount-Gambier collection the number will no doubt be increased. We miss from this locality the Mount-Gambier species *Cellaria* (*Melicerita*) *angustiloba*, Busk, and *Spiropora verticellata* (a species common in the European Chalk). The *C. angustiloba* may be represented by *C. globulosa*.

Twenty-two of the Chilostomata are known recent; and many more are very nearly allied to living forms.

Three species are already known in the Miocene? Muddy-Creek (Victoria) beds, and four Chilostomata and, at any rate, three Cyclostomata from the Eocene of Italy; but several others show relationship to the Miocene and Eocene forms, and we are frequently reminded of European Cretaceous ones, though in only one case could we feel justified in identifying the species with any from the Chalk.

It will, however, be well to defer further comparison until the list of the known Mount-Gambier species, upon which I am now engaged, is completed.

I have already * referred in various places to my reasons for using the term Bryozoa, which is now universally employed by German, French, and Italian authors; and I do not therefore need to enter again into the question. And although I am sorry that those few English authors who have been before the public for a long time have not been induced to change the name which they have used for several years, yet I have indications which cause me to feel quite confident that the next generation of English workers will use the class name which has been employed in the rich literature of Germany and France; and I am glad to see that Mr. Tenison Woods † has begun

* "On the Terms Bryozoa and Polyzoa," Ann. & Mag. Nat. Hist. Jan. and Feb. 1880; "Reply on the Term Bryozoa," *ibid.* Aug. 1880.

† "Corals and Bryozoa of the Neozoic period in New Zealand," Palæontology of New Zeal. pt. iv., Colon. Mus. & Geol. Surv. Depart. 1880.

to use this name, and to hear from Australia that it is there likely to immediately replace the term Polyzoa. It is therefore with much pleasure that I use the name in this contribution to the palæontological literature of that continent.

Though considering that modifications of the definitions of some genera is required through specimens now found, I leave that until I have completed my examination of the Mount-Gambier collection now in my hands.

The figures are all drawn with the camera lucida, and, as far as possible, magnified twenty-five times; but this is in each case stated by the side of the figure. I regret that Plates XV. and XVI. are so unsatisfactory through want of success in transferring the drawing to the stone; and, in fact, Plate XVII. came out so badly that I was obliged to have it very considerably touched up upon the stone, and much detail is thereby lost or altered. The Plates are also unsatisfactorily arranged, in consequence of my receiving the material at various times.

List of Species.

	Page.	Living.	Mount Gambier.	Orakei Bay.	Allies and Localities.
1. Catenicella cribriformis	317				
2. —— flexuosa	,,				
3. —— marginata	,,				
4. —— ampla	,,	...	*	...	*C. ventricosa*, B., living.
5. —— alata, *Thoms.*	,,	*	*	...	Australia.
6. —— elegans, var. Buskii, *Th.*	,,	*	...	...	Australia.
7. —— solida	318				
8. —— internodia	,,				
9. Cellaria fistulosa, *L.*	319	*	*	...	Miocene and Eocene of Europe.
10. —— malvinensis, *B.*	321	*	*	...	Falkland Islands.
11. —— ovicellosa, *Stol.*	,,	...	*	*	*C. tenuirostris*, var. *a*, Busk.
12. —— globulosa	,,	...	...	...	*Eschara aspasia*, d'Orb., Cretaceous.
13. Canda fossilis	322	...	*		
14. Caberea rudis?, *Busk*	,,	*	...	...	Bass's Straits.
15. Membranipora lineata, *L.*	323	*	...	...	Widely distributed.
16. —— catenularia, *James.*	,,	*	...	...	Pliocene.
17. —— cylindriformis	,,	...	*	...	*M. Flemingii*, living.
18. —— macrostoma, *Rss.*	,,	...	*	*	Bartonian, Italy, and Miocene.
19. —— argus, *d'Orb.*	324	...	...	...	Cretaceous.
20. —— concamerata	,,				
21. —— lusoria	,,	...	...	...	*Nellia simplex*, B., living.
22. —— maorica, *Stol.*	325	*	...	*	Upper Eocene, New Zealand.
23. —— geminata	,,				
24. Micropora patula	326	...	*		

List of Species (continued).

	Page.	Living.	Mount Gambier.	Orakei Bay.	Allies and Localities.
25. Cribrillina terminata	326	...	...	...	*Lepralia scutulata*, B., living.
26. —— dentipora	,,				
27. —— suggerens	327				*Cribrillina tubulifera*, Hincks.
28. Mucronella mucronata, *Sm.*	328	*	*	...	Florida, living.
29. —— duplicata	,,	*	*	...	Lyall's Bay, New Zealand.
30. —— elegans, *Macg.*	329	*?			
31. Microporella violacea, var. fissa	,,	*	*	...	Indian Ocean.
32. —— ferrea	330	...	*		
33. —— elevata, *Woods*	,,	...	*		
34. —— yarraensis	331	...	*		
35. —— coscinopora	,,				
36. —— ænigmatica	,,				
37. —— symmetrica	332				
38. —— clavata, *Stol.*	,,	...	...	*	
39. Porina clypeata	,,	...	*		
40. —— coronata, *Rss.*	333	*	*	*	Low. Eoc., New Zeal., Bart., Italy.
41. —— columnata	334	...	...	...	*Eschara heterostoma*, Rss., Eoc., Italy.
42. Lepralia corrugata	335				
43. —— monilifera, var. armata	,,	...	...	...	Pliocene of Europe.
44. —— spatulata	,,	...	*	...	*L. multispinata*, B., Madeira.
45. —— cleidostoma, *Sm.*, var. rotunda	336	*?	...	...	*L. cleidostoma*, Sm., Florida.
46. Porella emendata	,,				
47. —— denticulata, *Stol.*	,,	...	...	*	
48. Smittia centralis	337				
49. —— centralis, var. lævigata	,,				
50. —— Tatei, *T. Woods*	,,	...	*		
51. —— anceps, *McGill.*	,,	*			
52. Schizoporella vigilans	338				
53. —— phymatophora, *Rss.*	,,	...	...	...	Eocene of Italy.
54. —— ventricosa, *Hasw.*	,,	*?			
55. —— fenestrata	339				
56. —— sp.	,,				
57. —— sp.	,,	*	...	...	*S. biaperta.*
58. —— submersa	340				
59. —— conservata	,,	...	*		
60. —— spiroporina	,,				
61. —— excubans	341				
62. —— amphora	,,				
63. —— australis, *T. Woods*	,,	...	...	...	Muddy Creek (Miocene ?).
64. Retepora marsupiata, *Sm.*	342	*	*	*?	Miocene (America).
65. —— rimata	343	...	*		
66. Cellepora yarraensis	,,				
67. —— fossa, *Hasw.*	,,	*	*		
68. —— sp.	344	...	...	...	*C. pumicosa* (B., non Linn.).
69. Lunulites guineensis, *Busk*	,,	*			
70. —— cancellata, *Busk*	,,	*			
71. Selenaria marginata, *T. Woods*	,,	*			
72. —— alata, *T. Woods*	345	...	...	...	Muddy Creek (Miocene ?).

1. Catenicella cribriformis, sp. nov. Plate XVI. fig. 39.

Zoœcia wide, globose, with cribriform area below the aperture, with five pores on each side; large lateral avicularia (wings broken): linear vittæ nearly to the base; aperture rounded above (broken below, probably straight); reverse smooth.

This is larger than *C. hastata*, and has more pores; and the lines in the cribriform area are smaller.

2. Catenicella flexuosa, sp. nov. Plate XVI. figs. 40, 41.

Cells elongate, irregularly oval, large depressions above and at the side of the aperture; cribriform area small, with nine pores (fenestræ); aperture rounded on the distal edge, straight below. A wavy thick tube on the front, which may be abnormal; reverse smooth, raised over the upper and lower part of the first zoœcium and over the second zoœcium.

This has some of the characteristics of *C. alata*, Thoms.; and, with only the one imperfect specimen, it is doubtful if it should be described as new.

3. Catenicella marginata, sp. nov. Plate XVI. figs. 44, 45.

Zoœcia nearly cylindrical, a coffin-shaped margin round the zoœcium, and marginal bands enclosing depressions near the aperture of the corneous joint; aperture rounded above, doubtful below, seven distinct pores surrounded by a line; back smooth.

4. Catenicella ampla, sp. nov. Plate XVI. figs. 46, 50.

Cells large, subovoid, nine large pores (fenestræ) on the border of a large area (scutum); small longitudinal ridge above the aperture, with a depression on each side of it. Oral aperture rounded on the distal edge, proximal edge somewhat arched. Dorsal surface with a large grooved depression over the centre of each zoœcium; and by the side are two long adjoining chambers, which are probably covered by a membrane when living.

The lateral chambers are very characteristic, and somewhat resemble those in *C. ventricosa*, Busk: but in *ventricosa* they are lateral but turned partly towards the front, while in the present case the direction is dorsal. There is a faint median line, and lines branching off to each fenestra, which are not shown in the figure in consequence of the lithograph being badly put on the stone.

Loc. Mount Gambier (*Lond. Geol. Soc. coll.*).

5. Catenicella alata, W. Thoms. Plate XVI. figs. 47, 49, 58.

Catenicella alata, W. Thoms., "On new Genera and Species of Polyzoa from Coll. of Prof. Harvey," p. 80, pl. vi. fig. 4 (Zool. Bot. Assoc. Dublin, 1859, vol. i.).

Loc. Living. Fossil, Mount Gambier (*Lond. Geol. Soc. coll.*).

6. Catenicella elegans, Busk, var. Buskii, W. Thoms. Pl. XVI. figs. 42, 43.

Catenicella Buskii, Wyville Thomson, "On new Genera and

Species of Polyzoa from the Coll. of Prof. Harvey," Zool. Bot. Assoc. Dublin, vol. i. 1859, p. 83, pl. viii. fig. 2.

Cells almost cylindrical, contracted towards the base. There have been avicularia at both sides above the aperture. Aperture not perfectly preserved, rounded on the distal edge, with a constriction on each side near the base; proximal border (smaller than figured) slightly rounded. Vittæ distinct, with double row of pores in a depressed area.

The vittæ of the *Catenicellæ* are not correctly figured and described in the British-Museum Catalogue; for, instead of being raised areas with raised warts, they are sunken areas enclosed by raised edges, and along these sunken areas there are one or two rows of pores, according to the species. The vittæ, however, when covered with a membrane, may appear like raised areas; but an examination of the British-Museum specimens shows that the structure was not quite correctly appreciated, and it would be a great advantage if any one who undertakes the revision of the Catenicellidæ would give figures with all the membranes removed. The size of the recent and fossil species is identical.

In order to compare *Catenicella*, *Scrupocellaria*, and other more or less corneous forms, I made a series of calcined preparations of most of the recent specimens in my possession.

This is allied to *C. perforata*, B.

Loc. Living; Bass's Straits (*T.*), Australia (*my coll.*).

7. Catenicella solida, sp. nov. Plate XVI. figs. 37, 38.

Single cell oblong to cuneate, double cells ovate to globular; a straight band or ridge down the front of each cell, and a similar raised band separating the two zoœcia; a small curved ridge forming a circle on each side of the aperture, and below the aperture a linear band on each side. On each side of the central bands large pores (sometimes double pores). Oral aperture round above, with a small sinus on the proximal edge; a denticle on each side of the top of the sinus. Dorsal surface with several large depressions, bounded by bands similar to those on the front; the bands, both front and dorsal, are grooved. Avicularia very minute, angular or rounded (about half the length of the oral aperture), on the side of the cell near the distal end.

This is common in the Yarra-Yarra formation, where, however, the cells are usually found double, and the number of single cells seen is very limited. The bands vary somewhat in shape; but fig. 38 shows the typical form. This has many points of relationship with *C. ponderosa*, Wilson (Micr. Soc. Vict. vol. i. p. 63, pl. v. figs. 1–3), a living species; also with *C. carinata*, Busk; and *C.* species xii. of Wilson (*loc. cit.* p. 63), a fossil from Spring Creek, but I am unable to identify it with any described species.

8. Catenicella internodia, sp. nov. Plate XVI. figs. 78, 79.

Zoarium in distinct internodes of several zoœcia arranged in a bicellate series. Zoœcia suboblong, with a wide ridge down the middle of the zoœcium; the band spreads out at the top immediately below the aperture in an oval form, causing an oval depression surrounded by the band. The upper part of the zoœcium, comprising the aperture and this oval, is slightly raised; in the longitudinal depression four or five pores. On the inner side of the zoœcium, above the aperture; a small flattened boss; on the outer side a small triangular avicularium; a large depression or pore in the middle of the central band. Oral aperture semicircular, with the proximal edge straight; on the back an irregular oval depression behind each zoœcium, with from three to five pores in each of these depressions.

This is allied to *C. solida*, Waters (figs. 37, 38); but the shape of the aperture is different, besides considerable difference in the structure of the back. At first I thought the large holes in the middle of the centre band were accidental; but this is really not the case, as in the cells, when there is no hole there, it is replaced by a dark round spot, probably of thinner shell.

9. Cellaria fistulosa, L. Plate XIV. figs. 1, 2, 10, 11.

Cellaria fistulosa has occasioned systematists the greatest difficulty; and it now possesses a mass of synonyms (for which see Hincks and Reuss), of which many can never be compared. When I examined these and the allied species from this Victorian material, I at first felt that it would be impossible to separate them, and thought with Reuss that the range of variation was so great that such forms as *C. fistulosa*, *sinuosa*, *crassa*, *marginata*, &c. must be included under one specific name. Since my preliminary examination Mr. Hincks's most valuable work on the British marine Polyzoa has appeared, in which he distinguishes three species, *fistulosa*, *sinuosa*, *Johnsoni*. I have therefore, with this book before me, again very carefully examined my recent specimens, first calcining considerable portions; and the conclusions I have come to are:—that the shape of the cell is so variable that it is perfectly useless as a character (this has already been mostly recognized by recent writers, but was the character on which the species were some time ago principally founded); then I next found that the bordering rim, which is a character of *C. Johnsoni*, Busk, is sometimes found on one part of a colony of *C. fistulosa*, and absent in other parts; next I found the shape of the ovicellular opening equally unsatisfactory (for in most undoubted specimens of *fistulosa* from Naples it occurs in some cells as a minute orbicular opening, then it is elongate oval, and in other apparently older ovicells a broad semicircular line is formed, which changes to a transversely oval opening, resembling that figured by Mr. Hincks as a character of *C. sinuosa*). In the same specimen, before any ovicells are formed, the aperture is very near the top of the zoœcium; but afterwards its position is near the centre. Having found the position of the aperture, the shape of the ovarian opening, the shape of the zoœcium and of the bordering rim unsatisfactory characters, there only remained the avicularia; and in all the specimens I have examined I have found one form constant: the *fistulosa* from the Mediterranean has its rounded avicularium above the zoœcium; the *sinuosa* has a diagonal avicularium pointed downwards, with the lower part raised; the *Johnsoni*, from Rapallo (Italy) and New Guinea, has a zoœcial avicularium with a projecting hood above, as figured by Hincks. I find my observations on the recent species entirely confirmed by the examination of a large number of fossil forms.

Some thick specimens, such as fig. 1, have the characteristic avicularia of the European *fistulosa*; these are somewhat rare; but slender specimens, such as fig. 12, are common, and probably these are the same species; but as I have been unable to find any avicularia in these, both from Yarra-Yarra and Mount Gambier, the point cannot be decided with certainty. In the specimens figs. 10, 11, however, I find a small wide avicularium, as in larger *fistulosa*, with which these must therefore be united. The shape of these last resembles that of *C. Johnsoni*, which is the *C. marginata*, Reuss (Tert. Wien, p. 59, pl. vii. fig. 29, not 28); and I have slender *C. Johnsoni* from off Raton (New Guinea) resembling figs. 10, 11 in all except the avicularium, which is the large rounded one with which we are already acquainted in *C. Johnsoni*.

In fig. 11 we have an interesting specimen, as showing how very slender they may sometimes be; this has only one longitudinal row of cells on each of the four faces. In specimens from Mount Gambier, like my fig. 12, I have occasionally found in the oral aperture two teeth above and two teeth below, and in the ovarian openings sometimes one set of teeth, sometimes two; but these cannot be looked upon as constant characters, and lead us to think that *C. crassa* must be considered a doubtful species; or perhaps two species are represented, seeing that avicularia of two kinds are figured. I also sometimes find in the recent *C. Johnsoni*, from Rapallo, two such teeth in the upper part of the aperture, as well as the two below.

Fig. 1 shows that the joints of this specimen were attached by numerous horny tubes. In recent *C. tenuirostris* and *C. malvinensis* the joints are usually thus attached; but this is not the case in *C. fistulosa*; but in specimens of *C. Johnsoni*, from Rapallo, there are sometimes, though not usually, several such connecting tubes. This leads us to the consideration of these joints; for when a stem divides and two new branches are formed, the calcareous wall is continuous, and in some the branches are already large (perhaps throwing out fresh branches) before this calcareous wall is broken through. Of specimens I examined, I found this calcareous structure remained continuous longest in *C. Johnsoni*, but scarcely at all in *C. gracilis*, while *C. fistulosa* occupied a mean position; but much might depend upon the sea in which each specimen grew, as jointed structure in this and other genera must be looked upon as an adaptation to moving water. In fossil specimens from the Pliocene &c. permanent ankylosis, as already pointed out by Busk and Hincks, is frequent. I am not inclined to think that, as a rule, articulation can be made a basis of generic classification; and perhaps at some time the geological record may show us that jointed forms are all derived from unjointed ones.

Loc. Living, widely distributed. Fossil: Mount Gambier, common; and also from the Miocene and Pliocene of Europe; but as we cannot be quite sure from the descriptions of Reuss and others that *Salicornaria farciminoides* does not include other species, it is best to refrain from giving localities.

10. Cellaria malvinensis, Busk. Plate XIV. fig. 3.

Salicornaria malvinensis, Busk, Mar. Poly. p. 18, pl. lxiii. figs. 1, 2.

The zoarium is about the same size as *Cellaria fistulosa*, fig. 1; sometimes the cells are hexagonal, at others more acute above and below; an acute avicularium replaces a zoœcium. The front of the zoœcium is very much depressed, being surrounded by a raised border; distal edge of the oral aperture rounded, contracted above, so as to suggest a subtriangular shape; proximal edge curved inwards, with a small tooth at each side.

Loc. Living: Falkland Island, South Patagonia (*Darwin*). Fossil: Mount Gambier, common (*Lond. Geol. Soc. coll. & Eth. coll.*).

11. Cellaria ovicellosa, Stol. Plate XIV. figs. 4, 5, 6: Plate XVII. fig. 62.

Salicornaria ovicellosa, Stol. Foss. Bry. Orak. p. 151, pl. xx. figs. 9, 10.

From Yarra-Yarra I have several small fragments; and in some there is a rim round the cell, as figured by Stoliczka, and in others it is plain, as in fig. 4. The most interesting specimen is one in the possession of Miss Jelly (fig. 62), which shows the great range of variation and the great difficulty in determining species on the characters generally used—as, for instance, the mouth varies in position in the fertile and unfertile cells, and the zoarium, in this case, is quite thin (as in fig. 4) in the upper and lower parts; but in the middle the diameter is more than twice as great, and in this thicker part, where the cells are fertile, there are very large acute raised avicularia above the zoœcium, occupying nearly as much space as the zoœcium. Fig. 5 shows the position of the distal rosette plates, which are not quite in the centre of the zoarium. Fig. 6 shows the two lateral plates on each wall.

This is evidently very closely related to *Cellaria tenuirostris* (especially var. *a*) of Busk, from Bass's Strait, Tasmania, Florida, &c.; but it differs in having the upper part of the avicularium much projecting, and the rim is regular instead of being raised at the two sides.

Loc. Orakei Bay, New Zealand (*St.*); Mount Gambier (*Lond. Geol. Soc. coll.*).

12. Cellaria globulosa, sp. nov. Plate XIV. figs. 16, 17.

Zoarium consisting of joints, from the top of which arise two similar joints connected with the first by corneous tubes; internodes short, laterally subcircular, compressed. Zoœcia quincuncially arranged, hexagonal; oral aperture arched above, lower lip straight, with two distinct denticles, aperture placed one third the length of the area from the top; zoœcial area slightly depressed.

This differs from *Cellaria* (*Eschara*) *aspasia*, d'Orb. (Pal. Fr. p. 132, pl. dclxvii. figs. 14, 16), in having the cells distinctly hexagonal instead of spatuliform, and from *Melicerita angustiloba*, Busk, in having the cells arranged quincuncially instead of in transverse rows; consequently the distal borders are straight and in contact in *C. globulosa*, while the lateral borders are straight in *M. angustiloba*, B.

From specimens I have seen from Mount Gambier, *Melicerita angustiloba* certainly seems to be a jointed species, and should be united to *Cellaria*. The genera *Melicerita* and *Escharinella* are separated by d'Orbigny in consequence of the first having the cells transverse, while they are quincuncial in the second. *Latereschara* was also divided from *Eschara* on the same grounds.

Mr. Vine has in his possession a node from this locality, which is very irregular and elongate.

13. Canda fossilis, sp. nov. Plate XVI. figs. 51, 52.

Cells biserial; aperture elongate, rounded above, contracted below; upper margin recedent, with a spine on each side. Surface granulated. An avicularium (or spine) on the inner side of each zoœcium, placed about one third of the length of the zoœcium from the top. On the side a large pore for tubular fibre, above which is a vibraculum; on the dorsal surface cells arranged diagonally.

This much resembles *Canda arachnoides*, Lamx., but differs in having a smaller aperture, and in the pieces found there is no median avicularium; but possibly this may exist, as the diagnosis is based on a few small fragments. In *C. arachnoides* the cells on the dorsal surface are parallel with the median line.

Loc. Mount Gambier (*Lond. Geol. Soc. coll.*).

14. Caberea rudis, Busk?. Plate XVIII. fig. 86.

Caberea rudis, Busk, Cat. Mar. Polyz. p. 38, pl. xlvi.

Zoœcia elongate, oblong; aperture elliptical, occupying about one half of the front of the zoœcium; area sloping inwards, very minutely granular; a spine on each side at the top of the aperture, and a small opening (spinous or radicular) beyond the rim of the area; a small avicularium on one side below the area. So-called operculum large, entire, elliptical. Ovicell much raised, opening arched, rather flattened in front, with a line round the flat region. A small avicularium on one side near the top of the ovicell.

The fragment only consists of one row of cells; and therefore it is impossible to be quite sure of the determination; but if not *rudis*, it approaches very closely to it, and the vibracula apparently correspond.

The preservation of the operculum in so fragile a specimen was surprising; but I have also a specimen of *Caberea* from Mount Gambier with all the operculum remaining.

Loc. C. rudis is found in Bass's Strait (*B.*).

15. Membranipora lineata, L.

I have a small fragment of *Membranipora* consisting of two elongated cells with large area, with an acute avicularium above the cell, with beak pointing downwards, about sixteen large spines round the cell, and two smaller ones just above the border on the distal extremity. This seems to vary from the living *lineata* only in having more spines; but from so small a fragment it is impossible to speak with certainty.

16. Membranipora catenularia, Jameson.

For syn. see Hincks's Brit. Polyz. p. 134.

The specimens are small, consisting of only a few cells, but correspond exactly with recent specimens I have from the Semaphore, Adelaide, Australia.

Living: Northern seas, Brit., Medit., Canada, Australia. Fossil: Pliocene of England and Italy.

17. Membranipora cylindriformis, sp. nov. Plate XVII. fig. 74.

Zoarium cylindrical. Zoœcia not distinctly separated; area contracted above, expanded below, filled in for about a third of its length with a calcareous granular lamina. Aperture subcircular, flattened below, margin much raised; oral spines, two large and two small ones; small acute triangular avicularium above the area, and larger more elevated ones below placed transversely.

From the material marked "Yarra Yarra" I have only found a small piece; but from Mount Gambier I have larger cylindrical pieces. The form of the zoœcia is very similar to that of *M. Flemingii.*

Loc. Mount Gambier (*Lond. Geol. Soc. coll.* and *Eth., jun., coll.*).

18. Membranipora macrostoma, Rss. (in *Vincularicæ* forma). Plate XIV. figs. 18, 19.

Cellaria macrostoma, Rss. Foss. Polyp. d. Wiener Tert. p. 64, pl. viii. figs. 5, 6.

Biflustra macrostoma, Rss. Die foss. Anth. u. Bry. der Sch. von Crosaro, p. 274 (62), pl. xxxiii. figs. 12, 13; Ak. Wien, vol. xxix.

? *Biflustra papillata*, Stol. Foss. Bry. Orak. p. 154, pl. xx. figs. 14, 14*a*.

Flustrellaria macrostoma, Manzoni, I Brioz. foss. del Mioc. d'Austria ed Ungh. p. 67 (19), pl. xiii. fig. 46; Ak. Wien. vol. xxxvii.

Zoarium subcylindrical, or much compressed, a number of varicells. Zoœcium distinct, with a well-marked border. Aperture elongate oval, occupying nearly the whole of the front of the cell; sides of the area folded inwards, so that the aperture is in a deep depression. Small raised avicularia above the zoœcium in a horizontal or diagonal position. Distal rosette plates two, near the front of the distal wall.

Aperture 0·46 millim. long.

Loc. Oligocene (Bartonian), Val di Lonte (*Rss.*), Brendola, Colle Berici, Ferrara di Monte Baldo (A.-W.-W. coll.); Miocene, Nussdorf (*Manzoni*), Orakei Bay (*Stol.*), Mount Gambier (*Lond. Geol. Soc. coll.*).

19. Membranipora argus, d'Orb. (in *Vinculariæ* forma). Plate XIV. figs. 20, 21.

Vincularia argus, d'Orb. Pal. Franç. p. 253, pl. dclxxxix. figs. 1–4.

Zoarium erect, slightly compressed. Zoœcia quincuncially arranged in longitudinal lines, distinct, irregularly hexagonal, contracted below, not raised above the general surface. Aperture oval, occupying about one third of the zoœcium. Two distal rosette plates near the centre of the distal wall; lateral rosette plates several close together (fig. 20, *a*).

This differs from *M. macrostoma* in having a very much smaller aperture, which is not in so deep a depression. The aperture is 0·31 millim. long.

Loc. Cretaceous, Meudon (*d'Orb.*).

20. Membranipora concamerata, sp. nov. (in *Vinculariæ* forma). Plate XIV. figs. 22, 23.

Zoarium slender, erect, hexagonal in section, dividing dichotomously, about 0·5 millim. in diameter. Zoœcia in longitudinal lines quincuncially arranged, distinct, with raised border, concave, elongate, contracted slightly below; border much raised above the aperture, forming a raised arch. Aperture oval, occupying from one third to one quarter of the length of the zoœcium. Zoœcial avicularium at the junction of each branch. One distal rosette plate near the centre of the zoarium (fig. 23); two lateral rosette plates (fig. 22, *a*).

This is the most common fossil in the material, and much resembles *Vincularia gracilis*, d'Orb., from the White Chalk of France, but differs in being smaller and having a smaller aperture, and having six cells in a series instead of eight; but we now know that this last is not an important difference; perhaps the two should be considered varieties of one species.

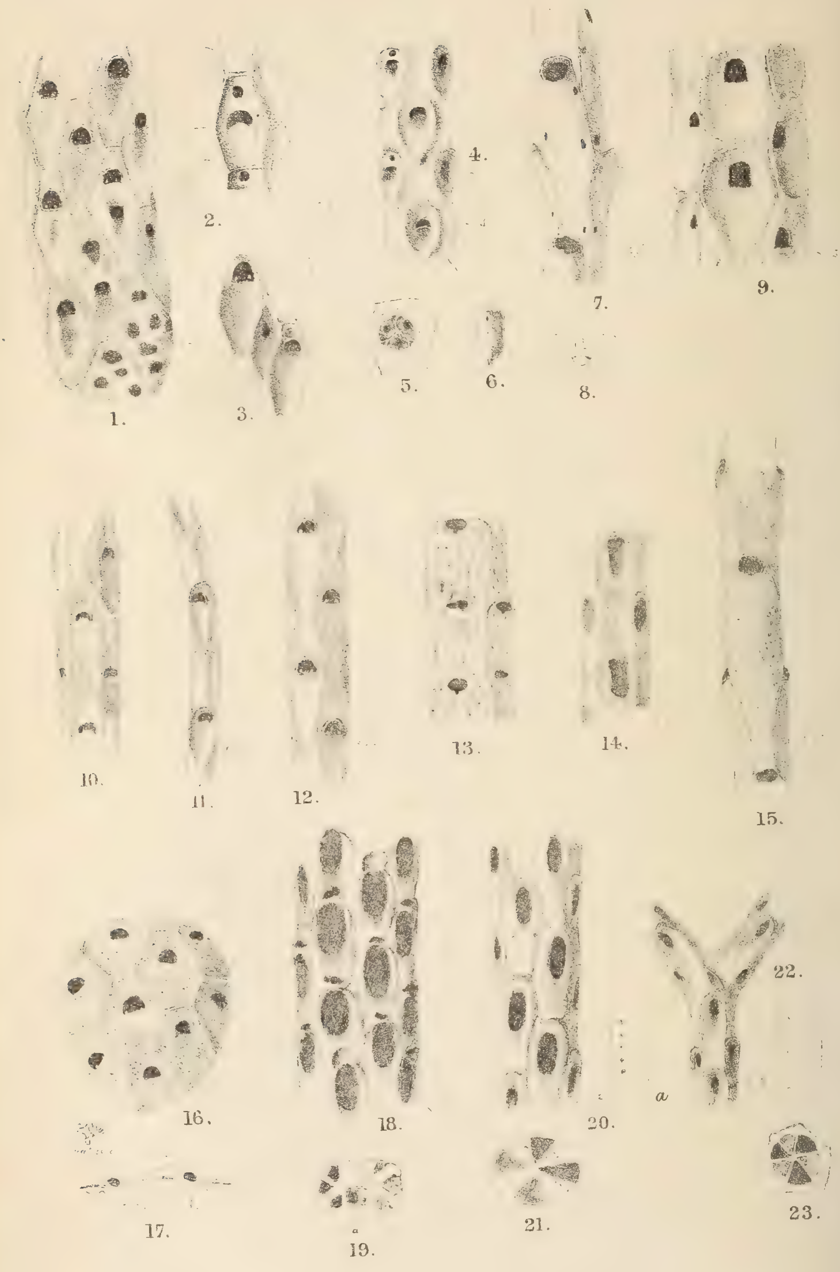
Aperture 0·14 millim. long.

21. Membranipora lusoria, sp. nov. (in *Vinculariæ* forma). Plate XIV. fig. 14; Plate XVIII. fig. 82.

Zoarium cylindrical, jointed, dichotomously dividing. Zoœcia suboval, rounded above, contracted below, distinct, surrounded with an elevated margin raised above the aperture. Aperture large, about one third the length of the zoœcium, oblong, rounded at the corners, contracted towards the middle. Very large elevated zoœcial avicularia directed downwards, with acute mandible.

Aperture 0·2 millim. long, 0·11 wide.

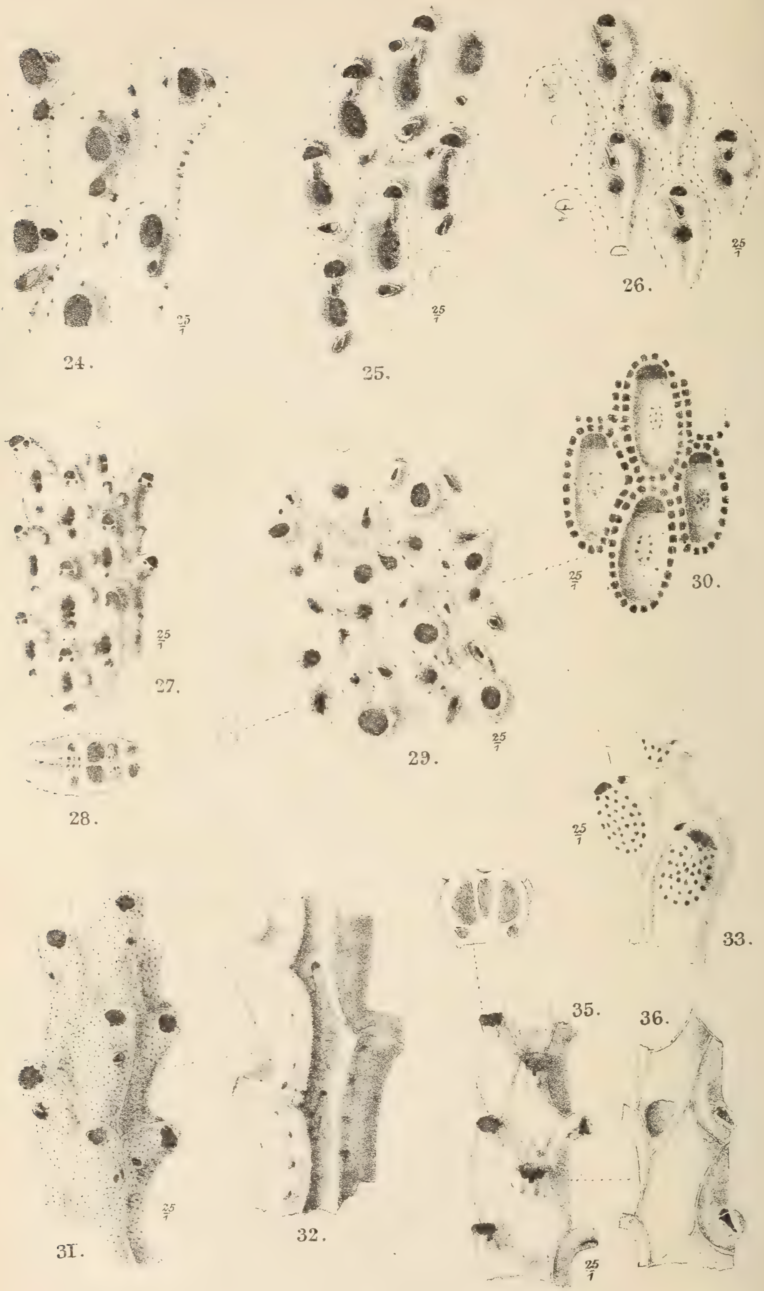
The form of the cell suggests a battledore, or, better, snow-shoes; and therefore, finding some difficulty in giving a distinctive name not



A. W. Waters lith.

Mintern Bros, imp.

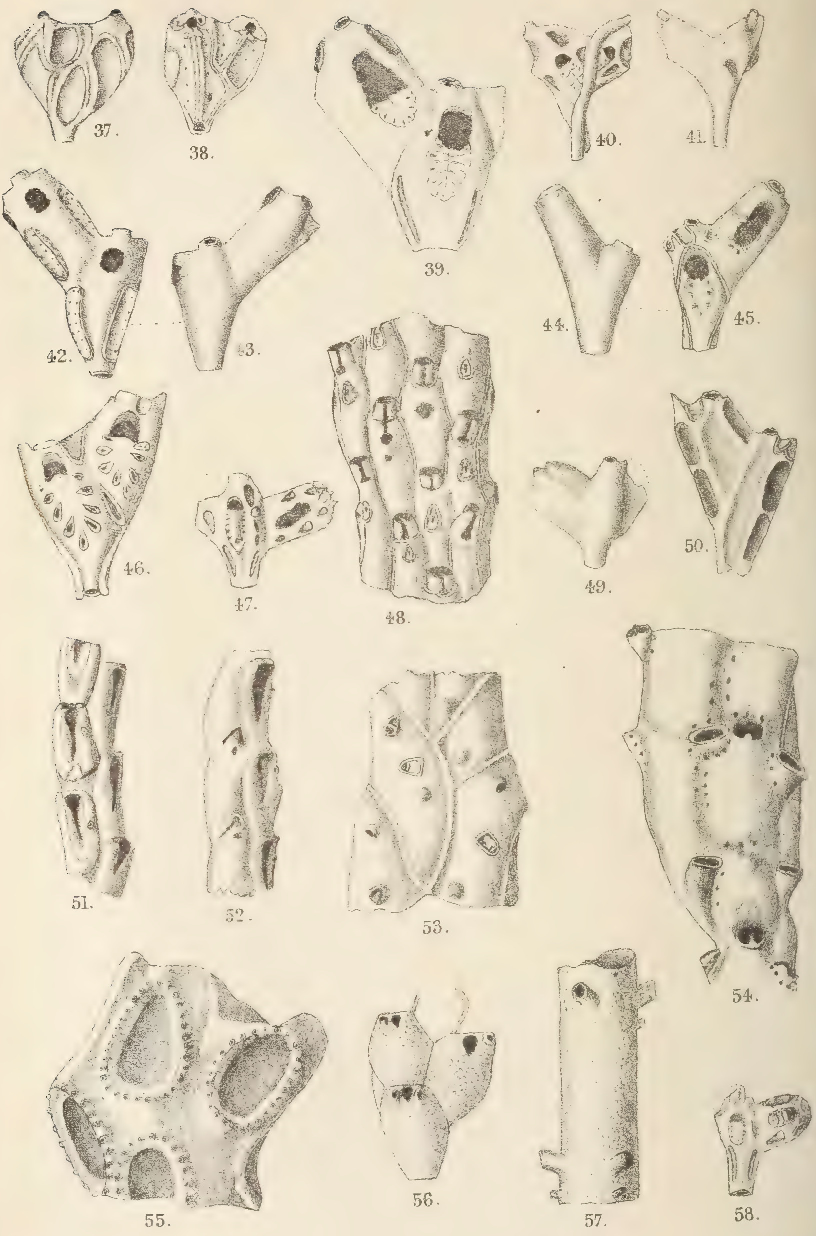
VICTORIAN FOSSIL BRYOZOA.



A. W. Waters lith.

Mintern Bros, imp.

VICTORIAN FOSSIL BRYOZOA.



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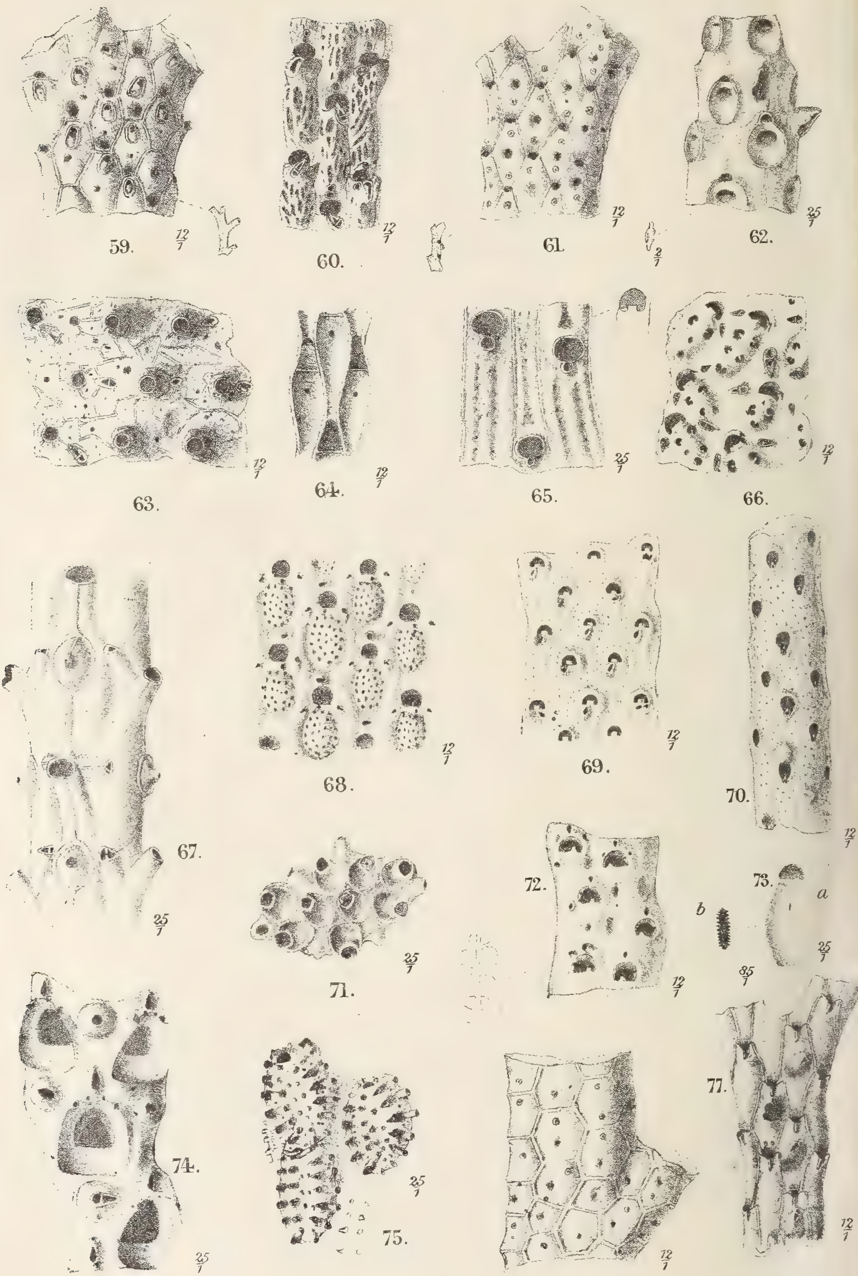
Mintern Bros, imp.

VICTORIAN FOSSIL BRYOZOA.

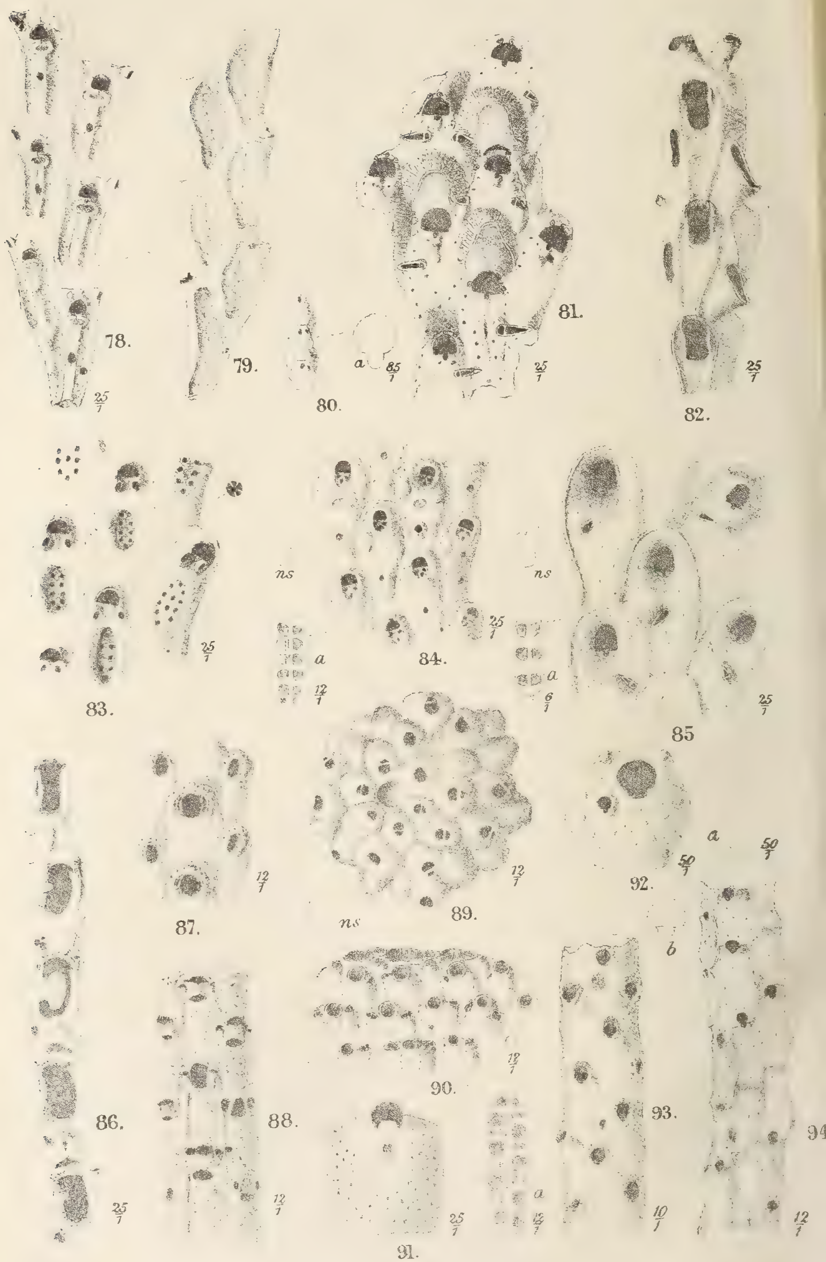
Mag. $\frac{25}{1}$.



A. W. Waters, lith.

Maclure & Macdonald, imp.

VICTORIAN FOSSIL BRYOZOA.



A. W. Waters. lith.

Maclure & Macdonald, imp.

VICTORIAN FOSSIL BRYOZOA.

employed in this or neighbouring genera, I have allowed myself to stretch a point in choosing a name. This would belong to *Nellia* of Busk; but that is a genus which, as defined, cannot possibly be maintained, and the present species with zoœcial avicularia shows how unsatisfactory a character the absence or presence of avicularia is. *Nellia*, Busk, is almost synonymous with *Quadricellaria*, d'Orb. This is very closely allied to *Nellia simplex*, Busk, from Prince of Wales's Channel, Torres Strait; the aperture in that case, however, is 0·5 millim. long and a regular ellipse, while in *M. lusoria* it is only 0·25 millim. long. Fig. 14 was drawn from a worn specimen without avicularia, before I had seen the one figured as 82; and then I could not make out all the structure.

22. Membranipora maorica, Stol. (in *Vinculariæ* forma). Plate XIV. fig. 9.

Vincularia maorica, Stol. Foss. Bry. Orak. p. 153, pl. xx. fig. 8.

Vincularia? maorica, Hutton, on some Austral. Polyz. p. 23, Rep. R. Soc. Tasmania, 1877.

Vincularia maorica, T. Woods, "Corals & Bryozoa of the Neozoic period in New Zealand," Palæont. of New Zeal., Col. Mus. & G. S. Dept. 1880, p. 27.

Zoarium erect, with six cells in a series, or, thickening out, in places there are eight. Zoœcia with a raised border, rounded, with a tendency to be hexagonal, calcareous, front of the zoœcia depressed, two tubercles above each zoœcium. Aperture (usually rather larger than figured) slightly trifoliate, distal edge rounded, and proximal edge straight. Avicularia large, occupying the place of a zoœcium. Two round rosette plates near the middle of the distal wall. (In the same position as shown in fig. 21.)

It is evident, from the description and the figure of the section, that Stoliczka's specimen was somewhat worn; and in such a case the cells would assume an entirely hexagonal form. The presence of the tubercles is indicated in his figure of the section. The avicularia are the same as those so common in many of the fossil *Membraniporæ*—for example, *M. angulosa*, Rss. (see my figure in Bry. of Bay of Naples, pl. xiii. fig. 3, Ann. & Mag. Nat. Hist. s. 5, vol. iii.); and it is interesting to find this with a distinctly Vincularian mode of growth. Smitt, when he broke up the old genera *Lepralia* and *Eschara*, indicated the colonial form by adding "*Lepralia-*, *Eschara-*, or *Hemeschara*-forma"; and we may further extend the principle by speaking of *Vincularia*-forma: thus the form of cell and the generic relationship will be shown, together with the mode of growth.

Loc. Living, Tasmania (*Hutton*). Fossil: Orakei Bay; Hutchinson's Quarry, Oamaru (New Zeal.); Upper Eocene of New-Zealand geologists.

23. Membranipora geminata, sp. nov. Plate XVI. fig. 55.

I have only found a small fragment of this; but it seems to be a branching form, with two cells diagonally to one side, followed by two cells turned towards the other side. Area an irregular oval, with margin thickened, much raised, surrounded by numerous spines.

24. Micropora patula, sp. nov.

Zoœcia distinct, divided by a scarcely raised thin border, subquadrangular, finely granulated with small pores, more numerous round the edges; distal portion of the zoœcium much depressed, raised above the distal edge of the aperture and forming a hood over it. Oral aperture rounded above, straight below, with a much raised lip or rim.

Aperture 0·25 millim. wide, 0·14 long.

This has some resemblance to *Vincularia binotata* and *cucullata* of Reuss and Manzoni; but the fragment is so small that we do not know if it grew in the *Vincularia*-form. The mouth is much larger; and also the zoœcial border is less distinct.

Loc. Fossil: Mount Gambier (*Lond. Geol. Soc. coll.*).

25. Cribrillina terminata, sp. nov. Plate XVII. fig. 68.

Zoarium in the *Hemeschara*-form. Zoœcia but very slightly raised, the plain borders of neighbouring zoœcia nearly confluent, so that the divisions of the zoœcia are scarcely visible; cribriform area somewhat depressed, the large pores concentrically arranged. Oral aperture rounded on the distal edge, straight on the proximal, contracted below. Small rounded avicularium above the aperture, a small one immediately below, a little to one side, and a small one on each side, just below the line of the aperture.

Oral aperture 0·13 millim. wide at base, 0·17 at widest part, 0·13 long.

This seems to have much in common with *Lepralia scutulata*, Busk (Q. J. M. S. vol. iii. 1855, pl. ii. figs. 1, 2); and it is difficult to know where it should be placed, as the pores do not seem to show any radial structure, and the aperture is contracted below, having the same shape as the oral aperture of *Diporula verrucosa*. It also has many points in common with *C. punctata*, and is one of those types which appear to be connecting links between widely separated forms.

26. Cribrillina dentipor, sp. nov. (in *Bactridii* forma). Plate XV. fig. 33.

Zoarium erect, with zoœcia only on the front; zoœcia growing from the side near the distal end of the zoœcium below, the axis of each zoœcium being thus diagonal to each of its neighbours. Zoœcia with a large raised cribriform area, the pores being placed concentrically, each pore with a denticle pointing away from the centre of the area. Oral aperture semicircular, with a straight proximal edge, 0·14 millim. wide. A small avicularium directed outwards on each side of the aperture. Dorsal surface with a central groove, and smaller depressions on each side.

The fragments are small, and not sufficient to found a new genus upon, which may possibly be necessary when large pieces are found;

for the zoœcia originating at the side is an important characteristic. The form of the cell, however, very closely resembles that of *Cribrillina terminata* (fig. 68); and by the present designation we, at any rate provisionally, show the zoœcial relationship and the mode of the zoarial growth. After finding that *Schizoporella phymatopora* (fig. 32) showed, when broken, a structure like *Bactridium*, I re-examined the present fragments, which, however, seem to belong to a form with cells on one side only, growing erect with only one series of cells. The British-Museum specimen of *Lepralia monoceros*, Busk, shows that the pores in that species also are provided with a denticle; but in that case the denticles are irregular.

27. Cribrillina suggerens, sp. nov. Plate XVII. fig. 75.

Zoarium in *Eschara*-form, consisting of two layers of cells growing back to back. Zoœcia oval, distinct, quincuncially arranged, with a double row of from twelve to fourteen erect tubular projections on the front, and a smaller row on the side, and some smaller ones in the central area; large pores between the tubes. Oral aperture small, semicircular, with straight proximal edge; in one case two curved irregular spines form a sort of arch over the aperture. A short triangular avicularium above the aperture on one side. Two oblong lateral rosette plates, one oblong distal plate.

Proximal edge of aperture 0·06 millim. wide.

This is a most curious and instructive form, in which we are at the outset met by a difficulty as to its generic position; for, looking at the aperture, we find it might belong to *Cribrillina* or *Mucronella*. With the latter, however, in other respects there is little in common; but with *Cribrillina* we find the radiating character of the pores, and, although no known species has such a bristling surface, yet in *C. Gattyæ*, *C. cribrosa*, Hell.*, *C. figularis*, &c. there is a row of slightly raised pores round the edge of the cribriform area.

These very curious prominent tubes (about 0·07 millim. high) naturally lead to the consideration of the signification of the pores and of avicularia; for may not avicularia have originated in such tubes having covers? and we may again ask, is the function of these tubes different from that of the pores which we almost universally find on the surface of the Bryozoa? The physiological signification of these pores is, perhaps, not sufficiently appreciated; and therefore a moment's digression is necessary, as we may thus have the record even in fossils of physiological structure. When a recent cell is decalcified, the membrane remaining shows small disks where the calcareous pore has been, and a spot in the centre of this disk further shows that to each one a thread of the endosarc has extended; so now we see that oxygenation, or a similar vitalizing change, takes place by means of the communication with the exterior through these pores. The front of a cell, however, frequently becomes covered with mud or organic growth; and in such cases raised tubes might be of great advantage in the economy of the colony: and if these

* See my fig. 4. pl. ix. in Bry. of Naples (Ann. & Mag. Nat. Hist. ser. 5, vol. iii. 1879), to which I have now to make addition.

are provided with a lid or "beak," they may still longer render assistance to the colony; for the polypide of a cell may be dead, and the cell itself covered with mud, but yet the zoarium may be living, and under favourable circumstances a new polypide may grow in this very zoœcium.

Modifications may take place, and the avicularia become highly differentiated, until we find them occupying the place of a zoœcium and of equal individual value with the zoœcia. Tracing it thus from below instead of from above, as is usually attempted, we get a much more reasonable explanation of the origin and function of the avicularia; for certainly when we find very minute avicularia on the root, and on the back of the zoarium, besides large numbers on the front of the cell, the prehensile theory seems utterly to fail; and although the present idea requires further development, yet the examination of living forms seems to furnish much to support it.

Smitt points out that in *Nellia oculata*, B., the papilliform processes are avicularia, sometimes with and sometimes without covers (mandibles); and we are constantly meeting with similar instances.

Mr. Hincks has kindly furnished me with an advance plate and description of *Cribrillina tubulifera*, Hincks (see Ann. Nat. Hist., July 1881, p. 8, pl. i. fig. 7), to which the present is closely related. The only important difference seems to be the relative size of the oral aperture, which is very small in the fossil. The specimen now described is very small; and it is to be hoped that a larger specimen may be found, upon which the affinities can be more exactly studied.

28. Mucronella mucronata, Sm. Plate XVII. fig. 66.

Escharipora mucronata, Smitt, Floridan Bryozoa, p. 24, pl. v. figs. 113–115.

? *Eschara Liversidgei*, T. Woods, "On some Tertiary Australian Polyzoa," Tr. Roy. Soc. New S. Wales, 1876, p. 3, figs. 11, 12, 13.

Zoœcia obscure, slightly elevated; aperture rounded above, straight below, with a mucro or broad, flat, plate-like expansion in front of the proximal edge; on the front of the zoœcia usually five large pores partially closed by a large, simple or bifurcate denticle, sometimes only three or four large pores, when there is usually a small rudimentary pore. Angular avicularia at the sides of the zoœcia; the two are usually unequal in size; a minute avicularium in the aperture. Probably incrusting or *Hemeschara*-form, from Yarra-Yarra. Aperture 0·23 mm. wide.

In the Mount-Gambier specimens in the Lond. Geol. Soc. collection there are usually only three pores, but sometimes four or five; and although the avicularia are not so distinct, and were not figured or described by Mr. Woods, yet they are to be seen at the sides of the zoœcia.

Loc. Living: W. off Tortugas, Florida. Fossil: Mount Gambier (*Woods* and *Lond. Geol. Soc. coll.*).

29. Mucronella duplicata, sp. nov. Plate XVI. fig. 54.

The fragment is small; but some characters are shown which are important, and by which it may be recognized again should it be found elsewhere.

The aperture is orbicular, with a mucro turning inwards over the aperture. On each side, below the aperture, there is a large avicularium, also one on each side two thirds of the distance from the next aperture. Above the aperture there is a raised area with a flat surface, apparently an ovicell. Above the ovicell and down the sides of the zoœcium there is a row of large pores.

The peculiar flatness of the ovicell is not shown in the drawing.

A specimen sent over to the British Museum by Mr. Hutton from New Zealand, marked and mentioned in his catalogue as *Lepralia variolosa*, seems to be this species. In the recent species the ovicells have a small umbo, and there is not a second pair of avicularia guarding the ovicells; but the position of the upper avicularia is the same, and the shape is similar. *M. duplicata* also occurs from Mount Gambier (Lond. Geol. Soc. coll.) with the zoarium erect, cylindrical, with one cell turned in each direction.

30. Mucronella elegans, Macg., var.? Plate XVIII. fig. 91.

? *Eschara elegans*, Macgillivray, "Austr. Poly." Trans. Roy. Soc. Vict. pt. ii. vol. ix. 1869, p. 138.

Zoœcia quadrate, surface finely granular with pores, except just below the aperture, a round avicularian pore immediately below the aperture. Oral aperture rounded on the distal edge, the proximal edge arched, forming a lip, a minute denticle on each side of the mouth immediately above the angles. Aperture 0·17 mm. wide; 0·1 long from the top of the lip to the distal end of the aperture.

Only two cells are preserved; and therefore it is impossible to be sure of even the generic position of the specimen; but it is evidently related to the species from Queenscliff and Portland Bay, described by MacGillivray as *Eschara elegans*, a name that should not have been given, as there is already *E. elegans* of Milne-Edwards. In *E. elegans*, MacG., no suboral avicularia are mentioned; but according to Mac Gillivray avicularia are sometimes situated at the side of the mouth.

31. Microporella violacea, Johnst., var. fissa. Plate XV. fig. 26; Plate XVII. fig. 73.

Microporella fissa, Hincks, "Contr. Gen. Hist. of Mar. Poly.,' Ann. & Mag. Nat. Hist. ser. 5, vol. vi. no. xxxv., Nov. 1880, p. 381, pl. xvii. fig. 4.

Zoarium in *Eschara*-form, flat, compressed. Zoœcia pyriform or oval, much raised, surrounded by a row of pores, or in old and worn cells covered with pores; a raised protuberance on each side of the zoœcium a little lower than the oral aperture; an avicularium immediately below the aperture, sometimes turned to the right, sometimes to the left; immediately below the avicularium there is a deep depression, and the opening of this depression seen from the interior is found to be an elongated denticulate pore (see fig. 73). Oral aperture rounded on the distal edge, straight on the proximal, 0·07 mm. wide.

It will be seen that this resembles the form of *M. violacea* called *plagiopora*, from the Crag, but differs in having an elongate pore; *Escharipora trifora*, Roem., from Söllingen, belongs to one of these forms. The old basal cells, where the oral aperture is obliterated, show a central depression for the pore and avicularium; and the whole cell stands out in a mamillated manner.

I have one specimen in which all the zoœcia are very much swollen on one side without any protuberance on the other; and in the same specimen, at the lower part of the avicularium, there are three openings, by which the mandible was probably attached.

Loc. Specimen in the Geol. Soc. coll. from Mount Gambier; but from this alone the detail could not have been worked out. Living: Indian Ocean (*H.*).

32. Microporella ferrea, sp. nov. Plate XVII. fig. 72.

Zoarium erect, in *Eschara*-form, compressed, few cells. Zoœcia indistinct, slightly raised round the oral aperture, depressed towards the centre, with a median pore. Oral aperture rounded on the distal edge, contracted towards the proximal edge, which is straight, thus having the shape of a circle with the lower third cut off. Small, erect, oral avicularia in the aperture, in one row on the right, in the next on the left; small avicularia and large pores round the raised portion surrounding the aperture; large zoœcial avicularia on the side of the zoarium, with the opening looking downwards. Oral aperture 0·14 mm. at proximal edge, 0·18 at widest part, 0·14 mm. long.

The large avicularium was (by an oversight) not figured; but the beak is about as large as an ordinary zoœcium, and it is just the same in form as the avicularia of *Cellaria ovicellosa*, fig. 62.

This would be *Diporula* of Hincks; but as I am doubtful about the necessity for the genus, I at present at any rate do not separate it from *Microporella*. A reference to my paper "On the Use of the Opercula in the Determination of the Cheilostomatous Bryozoa," Proc. Manch. Lit. and Phil. Soc. vol. xviii. no. 2, pl. i. fig. 28, will show that, in the form of the operculum, *Microporella (Diporula) verrucosa*, Peach, is very similar to the present species.

Loc. Fossil: Mount Gambier (*Lond. Geol. Soc. coll.*).

33. Microporella elevata, T. Woods. Plate XVII. figs. 63, 64; Plate XVIII. fig. 90.

Eschara elevata, T. Woods, "On some Tert. Austr. Bry.," Tr. Roy. Soc. N. S. Wales, 1876, p. 2, fig. 10.

Zoarium in *Eschara*-form, foliaceous, compressed. Zoœcia, in young cells (fig. 90), widely oblong to square, with a large short triangular avicularium pointing inwards on one side of the zoœcium on a level with the aperture, or frequently one such avicularium on each side; in the old cells the zoœcia are indistinct, with a much raised peristome giving a crateriform appearance; the general surface and the peristome divided by raised lines into angular areas, with one or two pores in each such area; below the aperture a large pore, which, however, is not always readily distinguished on the front of the zoœcium; but when examined from the interior (fig. 64) the round pore is always seen. Aperture of peristome round; oral aperture, as seen from inside, apparently with a straight proximal edge.

The right-hand side of fig. 63 is the lower part of the zoarium, being placed sideways to show the structure better. It is difficult to decide if this should be placed with *Microporella* or *Porina*.

Loc. Fossil: Mount Gambier (*Lond. Geol. Soc. coll.*).

34. Microporella yarraensis, sp. nov. Plate XV. figs. 27, 28.

Zoarium in *Eschara*-form, subcylindrical, compressed; branches dividing dichotomously. Zoœcium distinctly bordered, irregularly oval; peristome slightly raised. Oral aperture round on the distal edge, straight on the proximal; two large pores immediately below the aperture; the upper part of the zoœcium, supporting the aperture, together with these pores, is raised; a large protuberance on one side of the zoœcium, and a smaller one on the other. In the central portion of the cell a large depressed area with two or three openings; below this area a small avicularium. The zoœcium is surrounded with an indistinct row of pores. Three distal rosette-plates (see fig. 28). Oral aperture 0·6 mm. wide.

When the front of the cell is slightly worn and the aperture broken down, the aperture and pores together frequently give a subtriangular form to the resulting opening.

The details could not have been deciphered from the Mount-Gambier specimen, though when compared with the better-preserved specimens marked Yarra-Yarra it is seen to correspond in every particular.

Loc. Mount Gambier (*Lond. Geol. Soc. coll.*).

35. Microporella coscinopora, Rss., var. armata, nov. Plate XV. fig. 25.

This has a large distinct depressed cribriform area, and an avicularium below this area; the protuberances on the side of the zoœcia are wanting; and the surface of the zoœcium is flat; the upper part of the oral area is raised. Aperture 0·1 mm. wide.

In one specimen in Miss Jelly's collection there are similar small avicularia scattered irregularly over the surface.

36. Microporella ænigmatica, sp. nov. Plate XV. figs. 29, 30.

Zoarium in *Eschara*-form, composed of two layers back to back, forming a very thin lamella, which apparently has considerable extension (as all the pieces are flat and show no signs of branching). Surface of zoœcium very flat, opening of peristome circular; opening of oral aperture, as seen from the interior, arched above, straight below; depression below the aperture, closed by a cribriform plate; large and small acute avicularia scattered abundantly over the surface. Aperture 0·1 mm. wide.

The surface is very flat, and the openings of the oral aperture and avicularia being often of nearly the same size and irregularly placed, it is in some places impossible to decipher any structure. But in the best-developed and best-preserved parts the peristome is seen to be slightly raised; and at first it seemed that the form of the aperture indicated *Lepralia*; but the interior shows that the lower edge of the operculum was straight, and that it must be placed with *Microporella*.

37. Microporella symmetrica, sp. nov. Plate XVIII. fig. 83.

Zoarium in *Eschara*-form, foliaceous. Zoœcia hexagonally oval, distinct, with a thin border round the cell, scarcely raised, with few pores near the edge, raised in the region of the aperture, especially above the aperture. Two large openings, directed laterally immediately before the aperture; these are usually raised and form part of the peristome. An area on the lower part of the cell with stellate pores arranged in two series of 4 or 5, each regularly opposite to one another; sometimes one or two pores between the lateral rows. This area usually forms a deep depression; but in some cells this is not the case. Oral aperture semicircular, with straight proximal edge, 0·09 mm. wide, 0·07 mm. long.

In the species we see a marked likeness to *M. yarraensis* (fig. 27); and through these we are able to trace the relationship of this area from the round pore of *M. violacea* to the elongate pore of *M. violacea*, var. *fissa* (fig. 26), to the two or three pores of *M. yarraensis*, and the cribriform pores of *M. coscinopora* (fig. 25) and *M. ænigmatica* (figs. 29, 30), and, lastly, to the depressed area of the present species; and we seem justified in extending the comparison and comparing the non-depressed area of the present with that of *Cribrillina terminata* (fig. 68), which, in its turn, may be traced to typical *Cribrillina*.

38. Microporella clavata, Stol. Plate XVIII. fig. 84.

Flustrella clavata, Stol. Foss. Bry. Orak. p. 139, pl. xx. figs. 3, 5.

Zoarium in *Eschara*-form, forming thin foliaceous dichotomous branches or small round branches. Zoœcia suboval, contracted and truncate below; a characteristic semicircular depression immediately below the aperture, with three large raised pores, the two upper ones directed to the right and left. A laterally oval depression or opening about the middle of the zoœcium, with the median pore below this. Oral aperture semicircular, with a straight proximal edge, 0·07 mm. wide, 0·05 mm. long.

This is much the same as *Eschara tetrastoma*, Rss. Sitz. Ak. W. Wien. 1864, p. 9, pl. ii. fig. 9.

Loc. Fossil: Orakei Bay.

39. Porina clypeata, sp. nov. Plate XVII. fig. 67.

Zoarium erect, cylindrical; four zoœcia in a complete series, alternating regularly with each other, and facing in four directions. Zoœcia distinct, tubular; peristome much projecting; median pore placed about one half the length of the cell, opening at the top of a cone, the base of which is surrounded by an oval or circular rim, giving it a shield-like appearance. This rim is continued in a straight line above and below. A small obtuse avicularium on each side of the shield-like boss.

This is a very interesting specimen, as the shield-like elevation gives it a peculiar appearance different from any thing with which we are acquainted; and at first I did not know in what way the structure must be interpreted, and examined to see if it could be an ovicell, but think it must be considered homologous with the tubular pore of *P. tubulosa.* The specimens are all small.

Loc. Fossil: Mount Gambier (*Eth., jun., coll.*).

40. Porina coronata, Rss. Plate XV. fig. 57.

Cellaria coronata, Rss. Foss. Polyp. des Wien. Tert. p. 62, pl. viii. fig. 3.

Eschara conferta, Rss. loc. cit. p. 71, pl. viii. fig. 32.

Acropora coronata, Rss. Foss. Anth. & Bry. d. S. von Crosaro; Denk. math.-nat. Cl. k. Akad. der Wissensch. Wien, vol. xxix. 1868, p. 65, pl. xxxiv. figs. 33–55.

Spiroporina vertebralis, Stoliczka, Foss. Bry. Orak. p. 106, pl. xvii. figs. 6, 7.

Spiroporina vertebralis, T. Woods, "Corals & Bryozoa of Neozoic Period in New Zealand," Pal. of New Zeal. pt. iv. Colon. Mus. & Geol. Survey Dept. 1880, p. 23.

Porina Dieffenbachiana, Stoliczka, loc. cit. p. 135, pl. xix. fig. 20.

Porina Dieffenbachiana, T. Woods, "C. & Bry. of Neoz." loc. cit. p. 25.

Eschara Buskii, T. Woods, "On some Tert. Austr. Polyz.," Tr. R. Soc. N. S. Wales, 1876, p. $1\frac{4}{3}9$, figs. xvi. & xvii.

Myriozoum australiense, Haswell, "On some Polyzoa from the Queenland Coast," Proc. Linn. Soc. N. S. Wales, vol. v. pt. 1, 1880, p. 43, pl. iii. figs. 9–11.

This species has caused me much trouble, as its appearance in various conditions is very different; but direct comparison of typical specimens with *Acropora coronata* from Val di Lonte showed that the size, form of the cell, peristome, median pore, and small pore were sometimes just the same.

The zoarium is sometimes round and very slender, as in fig. 57; in others round and stout, as in Stoliczka's figure of *S. vertebralis*; but having a complete intermediate series, there is no doubt that they must be united. In other specimens, especially those from Mount Gambier, the branches are flattened as in *P. Dieffenbachiana*, Stol., fig. 20. The surface sometimes has small elongate pores, in other cases larger and round ones. In the slender specimens the pores are finer and more elongate, while in the stoutest they correspond with the pores of the Italian *P. coronata.* Again, the peristome in young cells is very thin and projects considerably; while in older specimens the large pores in the walls of the peristome are more distinctly seen; and in very well preserved specimens the walls of these project, so that each peristomial pore may be said to have itself a peristome. The median pore is usually about one quarter of the length of the zoœcium from the oral aperture, but sometimes much nearer; and in old cells, where the peristomial wall is much thickened, it approaches very close to the peristome, and almost becomes part of the peristomial crown. I have only one or two specimens in which there is a slightly projecting tube for this median pore; and in all other cases it is depressed. In some specimens, besides the small surface-pores, there are larger ones, which have in most cases been avicularia; and in a few specimens there is a larger spatulate avicularium above the oral aperture.

In a recent specimen in the *vertebralis* condition, from Darnley Island, I found that a section made from one end showed the central spongy structure with which we are acquainted in the old genus *Myriozoum*, while a section made from the other showed the cells ranged round the circumference but not meeting in the centre; and a section is thus figured by Mr. Haswell (*loc. cit.* fig. 10).

Stoliczka, in his figure, distinctly showed this *Myriozoum* character; and it is strange to find that he nevertheless placed the species among the Cyclostomata. The slender forms so nearly correspond with *Porina borealis*, Busk (especially as figured by Smitt in his 'Floridan Bryozoa,' pl. vi. fig. 144), that, if not the same, they are closely related to it; and the species is also related to *Porina filograna*, Goldf., figured in d'Orb. Pal. Franç. pl. 626. figs. 5–10, a common species in the Senonian, and also figured by Hagenow as *Eschara Defrancei*. Several of Hagenow's species with other names may represent worn specimens, as pointed out by d'Orbigny.

Although the different conditions pass so gradually from one to another that it is impossible to separate them, it may perhaps be useful to speak of them as condition (*a*) slender, as fig. 57; (*b*) stout, as *vertebralis*, figured by Stol.; (*c*) more flattened, and showing the quincuncial arrangement more clearly, as in *Dieffenbachiana*.

Loc. Fossil: Bartonian, Val di Lonte (*Rss.*), Montecchio Maggiore (*Rss.*), Vienna (*Rss.*); Ferrara di Monte Baldo, Crosaro, Brendola (all in my coll.); Hutchinson's Quarry and Oamaru, New Zealand, in Lower Eocene of New-Zealand geologists (as *c*, *Woods*); Hutchinson's Quarry, Upper Eocene ditto; Shakespeare Cliff, Upper Miocene ditto (as *b*); Orakei Bay, New Zealand (*b* & *c*, *Stol.*); Mount Gambier (*Woods*, *b* & *c*); and common in the Lond. Geol. Soc. coll., and also Eth., junr., coll. from Mount Gambier (as *b*).

Living: as *b*, Holborn Island, Queensland, 20 fathoms (*Hasw.*), and Darnley Island, Torres Strait, in material sent me by Mr. Brazier, from soundings in 10–30 fathoms.

41. Porina? columnata, sp. nov. Plate XVIII. fig. 88.

Zoarium cylindrical, erect, with six cells in a complete series, consisting of two rows of three each. Zoœcia irregularly oblong, with nearly parallel sides, distinct, separated by a wide rounded ridge, surface rounded, with much-raised acute granulations; the peristome forms a closed arch over the lower part of the oral aperture; the opening at the base of this arch is wide and laterally oval; a large tubular avicularium on each side of the peristome, also raised and continuous with the peristome. Oral aperture rounded below, probably round to saddle-shaped, somewhat contracted above.

The specimen is in a bad state of preservation; and diagnosis has to be made from the characters in various cells; consequently the figure is, to a large extent, a restoration, which is not the case with the other figures. I have shown the effect when the aperture is broken down in different degrees: when completely worn away, three nearly equal openings are seen, the central one being somewhat the largest; in other cases an elongate opening is formed, bounded on the top by the distal end of the peristome, and below by the base of the subperistomial opening.

This is closely related to *Eschara heterostoma*, Reuss (Bry. von Crosaro, p. $\frac{62}{274}$, pl. xxvi. fig. 5), which we believe is synonymous with his *E. duplicata* (loc. cit. p. (61 sep.) 273, pl. xxxiii. figs. 8, 10), from the Italian Eocene.

The shape of the oral aperture would seem to be Lepralian, perhaps much the same as in *Lepralia Pallasiana*; and it is somewhat a matter of doubt where this form should be generically placed. There are some species as yet undescribed from the southern hemisphere, with an arch more or less enclosing the aperture; and until these have been examined, it must be placed with *Porina*.

Since the above was written, Mr. S. O. Ridley has published, in the Proc. Zool. Soc. 1881, an "Account of the Zoological Collection made during the Survey of H.M.S. 'Alert' (pt. Polyzoa)," and describes and figures an incrusting species with cells much resembling those of *P. columnata*. For this he forms the genus *Gigantopora*, and points out the similarity to *Hippothoa fenestrata*, Sm., which seems to sometimes occur in an erect form; and these three species are evidently closely related; but we provisionally retain the present one under *Porina* until more complete specimens furnish further characters upon which the genus can be founded.

42. Lepralia corrugata, sp. nov. Plate XVII. fig. 60.

Zoœcia elongate, distinct, raised; surface in irregular ridges and furrows; in the furrows a row of one or two pores; lower part of zoœcia depressed, upper raised, with a large angular avicularium forming a kind of peristome over the lower part of the aperture; one or two large pores at the lower part of the zoœcium, just above the aperture of the zoœcium next below. Aperture rounded. Zoarium either incrusting or in *Eschara*-form.

Oral aperture 0·14 mm. wide.

43. Lepralia monilifera, M.-Ed., var. armata. Plate XV. fig. 24.

Zoœcia elongate, pyriform, raised in the centre, with a row of pores round the border; aperture oval, proximal edge slightly less rounded than the distal; a small angular avicularium on one or both sides of the aperture; in some cells larger angular avicularia below the aperture.

Aperture 0·11 mm. wide; 0·14 mm. long.

Only a small fragment, worn at the back.

44. Lepralia spatulata, sp. nov. Plate XVIII. fig. 87.

Zoarium erect, forming a solid stem, with zoœcia all round.

Zoœcia hexagonal, distinct, with a thin border slightly rounded, raised towards the aperture; surface finely granular; the region above the aperture is much raised, with six spines, three on each side. Aperture nearly circular, slightly elongate, situated in a wide depression, caused by the elevation round the sides and distal part of the aperture. Aperture 0·15 mm. wide, 0·17 long.

This much resembles *Lepralia multispinata*, Busk, from Madeira (Q. J. Micr. Sc. new ser. vol. i. 1861, p. 78, pl. xxxii. fig. 5); but the lip below the aperture is entirely wanting.

In a specimen from the Mount-Gambier collection of Mr. Etheridge, jun., there are many large spatulate zoœcial avicularia scattered over the stem.

Loc. Fossil: Mount Gambier.

45. Lepralia cleidostoma, Sm., var. rotunda. Plate XVIII. fig. 92.

Zoarium apparently flat and incrusting. Zoœcia small, distinct, hexagonal; surface coarsely granular. Oral aperture orbicular, contracted at the sides by two denticles; raised rounded avicularium (perhaps with vibracular characters) below the line of the aperture, on the side of the zoœcium; four lateral rosette-plates, one distal near the base of the zoœcia. Oral aperture 0·1 mm. wide, 0·13 long.

It is difficult to know where this should generically be placed. From the rounded distal and proximal edges of the aperture, it would have gone with Smitt's earlier definition of *Escharella*. In the size and form of the cells it much resembles *Schizoporella excubans*, fig. 56; but this, instead of being an erect quadrilateral form, is incrusting, and has a rounded avicularium; but we may perhaps here trace the passage from a definite sinus to a rounded proximal edge. It only differs from *Lepralia cleidostoma*, Smitt (Flor. Bry. p. 62, pl. xi. figs. 217–219), in having the rounded avicularium instead of an acute one, and should, perhaps, be united to it.

I have an erect branching form, with ovicells, from the Mediterranean, closely allied to this, which I hope shortly to describe and figure.

Mr. Hincks has kindly informed me (*in litt.*) that he has this variety from Bass's Straits.

46. Porella emendata, sp. nov. Plate XVII. fig. 69.

Zoarium in *Eschara*-form.

Surface nearly flat; cell-wall thickened round the oral aperture. Zoœcia elongate, expanded above, contracted below; row of pores in a furrow on each side of the zoœcium. Aperture round on the distal edge, straight on the proximal, with a very large denticle set deeply in the aperture. Small triangular avicularium below the mouth, usually placed somewhat diagonally.

Aperture on proximal edge 0·07 millim. wide, 0·06 millim. long.

47. Porella denticulata, Stol. Plate XVII. fig. 70.

Flustrella denticulata, Stoliczka, Foss. Bry. Orak. p. 138, pl. xx. fig. 2.

Oral aperture arched above, contracted below, enclosing an avicularium surmounted by a denticle; faint lines on the surface indicate the zoœcial divisions. Ovicell subimmersed, without any pores.

Loc. Not very common in Orakei Bay.

48. Smittia centralis, sp. nov.

Zoarium slender, erect, quadrangular, with the zoœcia on all four faces. Zoœcia separated by a ridge, elongate, oblong, flat, with a double row of pores on both sides of the zoœcia near the edge, with the peristome very much raised and projecting, with a large pore (probably avicularian) immediately below the orifice; peristome transversely oval.

49. Smittia centralis, var. lævigata. Plate XIV. figs. 7, 8.

Differs from the above in having the surface of the zoœcia slightly rounded; and instead of the two rows of small pores, there are a few elongate pores near the edge of the zoœcia; the peristome is less well preserved; and from these small fragments it would be impossible to be sure of the generic position of the species. The distal rosette-plates (fig. 8) are near the centre of the zoarium, from which circumstance the name is chosen.

50. Smittia Tatei, T. Woods. Plate XVII. fig. 65.

Eschara Tatei, T. Woods, "On some Tert. Austr. Fossils," Tr. R. Soc. N. S. W. 1876, p. 3, fig. xv.

Zoœcia elongate, with parallel sides, contracted below, surrounded by a narrow raised margin; two perforated furrows down the front. Aperture raised, rounded, with a second rounded opening immediately below (this is probably avicularian). Seen from the interior, there is a large denticle expanded at the top (fig. 65 *a*).

Aperture 0·13 millim. wide.

In consequence of the imperfect state of fossilization of the Mount-Gambier fossils, the aperture presents the appearances figured by Mr. Woods. A specimen in the collection of Mr. Etheridge, jun., shows cells as figured by Mr. Woods, and resembling those from the present collection.

Loc. Fossil: Mount Gambier (*Woods* and *collection of Mr. Etheridge, jun.*).

51. Smittia anceps, MacG. Plate XVIII. fig. 94.

Lepralia anceps, MacGillivray, Prodr. of Zool. of Vict. decade iv. 1879, p. 23, pl. xxxv. fig. 6.

Zoarium cylindrical; in one specimen four or five cells in a series, in another a hollow cylinder 2·5 millim. in diameter. Zoœcia subrhomboidal, sometimes hollowed in front, elevated towards the orifice, bounded by a prominent irregular sinuous line; surface very finely granulated, with large pores, more numerous near the edge. Oral aperture rounded on the distal end; the proximal edge is formed by the arc of a smaller circle.

When the aperture is seen from inside, we find a broad denticle (fig. 94 *a*); and when we look upon this denticle from above, it is seen to bear a very minute avicularium. Aperture 0·1 millim. wide, 0·14 millim. long.

If I had been unable to see the interior of the zoœcium, I should have considered this to be *Schizoporella sinuosa*, B., with which it corresponds in most particulars. I have examined the interior of *S. sinuosa* from Shetland, in which there is no similar denticle or avicularium. Some of the zoœcial areas have no aperture; and in these there are few or no pores.

52. Schizoporella vigilans, sp. nov. Plate XIV. fig. 13.

Zoarium erect, quadrilateral, with zoœcia on the four faces. Zoœcia irregularly oblong; surface flat, with elongated pores (reminding us of those of *Hornera*); upper part of the zoœcium slightly raised. Oral aperture rounded on the distal edge, nearly straight on the proximal, with a well-marked sinus. Acute avicularia, placed horizontally in the middle of the front wall of the zoœcium.

The proximal edge of the oral aperture is slightly straighter than figured. Aperture 0·08 millim. wide, 0·07 millim. long.

53. Schizoporella phymatopora, Rss. Plate XV. figs. 31, 32.

Eschara phymatopora, Reuss. "Foss. Anth. u. Bry. von Crosaro," Denschr. Ak. Naturwissensch. Wien, vol. xxix. 1869, p. 272 (60), pl. xxxiii. fig. 1.

Zoarium cylindrical. Zoœcia irregularly oval, not much raised; border distinct. Aperture circular, with sinus below. Avicularia at about one third or the middle of the length of the zoœcium, placed on one side; surface of zoœcium covered with pores and fine granulations.

When I drew fig. 32, I supposed that this was *Bactridium*, and allied to *Bactridium Hagenowi*, Rss.; and then I called it *triserrata*, as in all the fragments I had there were three rows of cells. Since then fragments in my own and in Miss Jelly's collection have shown that it is cylindrical. The species splits up with considerable regularity; and then the other sides of the zoœcia are seen with their lateral rosette-plates appearing like a row of pores. A central furrow is also seen with two rosette-plates for the entrance of the endosarc. The avicularia are usually much lower than figured by Reuss in his specimen from the Val di Lonte, but in some Australian specimens are higher than in my figure 31. Aperture 0·07 millim. wide.

Loc. Val di Lonte (*Rss.*); Ferrara di Monte Baldo (*A. W. W.*): Bartonian.

54. Schizoporella ventricosa ?, Haswell (in *Onchoporæ* forma).

Onchopora ventricosa, Haswell, "On some Polyzoa from the Queensland coast," Proc. Linn. Soc. N. S. Wales, vol. v. pt. i. 1880, p. 36, pl. i. fig. 3.

There is only a small fragment, which has the zoarium cylindrical, and which seems to branch without joints. It seems to correspond with the above; but there is reason for doubting whether too many species have not been made, as *Onchopora ventricosa*, Hasw., and *O. granulosa*, H., are very closely allied.

Loc. Holborn Island, Queensland, 20 fathoms.

55. Schizoporella fenestrata, sp. nov.

Zoarium in *Eschara*-form. Zoœcia indistinct, surface smooth. Oral aperture very large, in a very deep depression, rounded on the distal edge, with a sinus on the proximal; a small rounded avicularium within the oral depression, and a small rounded one below the aperture with avicularium opening with numerous denticles. Very large, erect, angular avicularium between the zoœcia. Oral aperture 0·17 millim. wide.

The large deep depressions round the large aperture, together with the smooth surface and small avicularia, gives the zoarium the appearance of the network of *Retepora*; and the specimen was sent to me marked *Retepora*. I therefore call it *fenestrata*, although, of course, it is clear that it is here the magnified aperture which represents in appearance the unmagnified fenestræ of *Retepora*.

56. Schizoporella, sp.

Zoœcia perfectly parallel, oblong, distinctly divided laterally, terminal divisions scarcely distinguishable. Surface smooth. Oral aperture large, 0·3 millim. long, 0·22 millim. wide, rounded above, apparently triangular below; frequently a notch on one side, as if regularly broken down; perhaps there is an avicularium inside the aperture below the notch. The back of the cells is also smooth, showing the lateral parallel divisions distinctly, with an oval opening 0·4 millim. long, *i. e.* about half the length of each zoœcium.

There are one or two species in which there is a similar oval opening on the dorsal surface; but at the present moment I do not find any note or reference to such, except in *Hemeschara geminipora*, Rss.

57. Schizoporella, sp.

This somewhat resembles *S. biaperta*; but the state of preservation is not sufficiently satisfactory for definite determination. The aperture is much smaller than in the last species; and there are numerous round avicularia scattered over the cell. The walls of the ovicells, which have been considerably raised, are broken down. This may be *Escharipora Lawderiana*, Stol. (Bry. Orak. Bay, p. 136, pl. xx. fig. 1); but the figure and description are so unsatisfactory that it is impossible to know where Stoliczka's specimen should be placed. The fossil specimen is in the *Eschara*-form.

A specimen in the British Museum, sent by Mr. Hutton, marked *Lepralia reticulata*, seems to be this species. The oral aperture of the recent specimen is rounded on the distal end, with a smaller arc forming a sinus on the proximal.

58. Schizoporella submersa, sp. nov. Plate XVIII. fig. 85.

Zoarium in *Eschara*-form, consisting of narrow foliations. Zoœcia suboval, expanded above, contracted below, distinct, surrounded by a raised border, partially concave, few pores on the surface. Acute avicularium near the centre of the zoœcium, sometimes directed diagonally upwards, sometimes downwards. Oral aperture very long, rounded on the distal end, with a small sinus on the proximal. The aperture is much depressed, giving the appearance of two wide denticles at the bottom of the oral pit. Aperture 0·07 millim. wide, 0·12 millim. long (to end of the sinus).

The upper part of the zoœcium being depressed gives a concave appearance to the zoœcia.

59. Schizoporella conservata, sp. nov. Plate XVIII. fig. 81.

Zoœcia suboval to oblong, distinct, not much raised, sometimes with a median raised ridge extending from the sinus; a few large pores near the edge; surface smooth; three spines above the oral aperture, and one on each side at the base of the aperture; surface slightly raised below the sinus. Oral aperture semicircular, rounded on the distal edge, straight on the proximal, with a small sinus which widens out below. An avicularium on one or both sides a short distance below the oral aperture; these vary from short triangular to acute lanceolate, pointing laterally outwards at right angles to the axis of the cell. Ovicells very large, elevated, with the central part plain, and nearly flat, the exterior walls beautifully ornamented with radiating lines with three pores between each. Aperture 0·16 millim. wide, 0·12 millim. long (to the straight proximal edge).

When the avicularia are small, they are raised; but when large, they are immersed. The dorsal surface is hexagonally divided, with an elongate oval space (about half the length of each zoœcium) of thinner shell. This perhaps corresponds with the "flattened disk" mentioned by Mr. Busk in *Microporella Malusii*, Aud. (Mar. Poly. p. 83); but it is by no means a constant character in *Malusii*, as the centre of the dorsal surface is usually depressed, with irregular elevations near the edge of the zoœcium. The structure of the dorsal surface of *Schizoporella conservata* must probably be compared with that of *Schizoporella*, sp., No. 56. I presume this species grew in the *Lepralia*-form.

Loc. Fossil: Mount Gambier (*Lond. Geol. Soc. coll. and Eth., Jun., coll.*).

60. Schizoporella spiroporina, sp. nov.

Zoarium cylindrical; zoœcia in annular series of six cells; series 0·7 millim. apart. Zoœcia indistinct, except towards the peristome; peristome much raised in front, but very little behind. Oral aperture at the base of the peristome, nearly circular, rounded at the distal end, with a wide sinus at the proximal. Large pores, perhaps avicularian, near the peristome.

This may be *Spiroporina immersa* of T. Woods (Corals & Bry. Col.

Mus. & Geol. Survey New Zealand, pt. iv. p. 23); but I must confess to being unable to understand Mr. Woods's description of the mouth. The specimen from "Yarra-Yarra" is very small and in imperfect preservation.

61. SCHIZOPORELLA EXCUBANS, sp. nov. Plate XVI. fig. 56; Plate XVIII. fig. 80.

Zoarium erect, filiform, with a longitudinal row of zoœcia on each of the four faces. Zoœcia distinct, subhexagonal, upper part much raised, surface granular. Oral aperture depressed, rounded on the distal edge, contracted on each side near the proximal edge, forming a large rounded proximal sinus. Triangular avicularium on raised prominence on a level with the oral aperture, directed downwards. Avicularia sometimes absent, usually on one side only.

Aperture 0·08 millim. wide, 0·075 millim. long.

Probably the genus *Schizoporella* will have to be broken up, and those forms in which the proximal edge of the oral aperture forms a large arc will be separated; for while the appearance is that of a large sinus, the structure must be different. It is also very difficult to see where the division should be made between *Lepralia* and *Schizoporella*; for the wide rounded aperture of *Lepralia* with two lateral denticles sometimes approaches very closely in shape that of a *Schizoporella* with a large and wide sinus. Fig. 56 was drawn from a small fragment in which it was impossible to see the form of the zoarium, and therefore, in this respect, is not quite correct. I have since received specimens showing the erect filiform growth.

62. SCHIZOPORELLA AMPHORA, sp. nov.

Zoarium slender, erect, with a single row of zoœcia on each of the four faces, the opposite pairs alternating with the other two. Zoœcia irregularly ovate, expanded and raised in the middle, contracted above and below: distal end of the zoœcium much raised, forming a small peristome which is contracted on both sides near the lower part.

The specimen is small; and more perfect ones may add many particulars. It may have been sometimes articulated, as seems to have been the case with *Cellaria Schreibersi*, Rss.

63. SCHIZOPORELLA AUSTRALIS, T. Woods. Plate XIV. fig. 15.

Tetraplaria australis, T. Woods, "On some Austr. Tert. Foss. Corals & Polyzoa," Tr. Roy. Soc. of New S. Wales, 1878, p. 5, fig. 4.

Zoarium cylindrical, slender. Zoœcia facing four ways, the opposite pairs alternating with the other two, elongately pyriform; surface very finely granulated, with extremely fine pores between the granules (but these can only be seen when the preservation is very good). Oral aperture rounded on the distal edge, slightly curved or straight on the proximal, with a small distinct sinus; aperture 0·08 millim. wide, 0·07 millim. long.

Since I drew the figure I have received a much better specimen, from which I have been able to make out the character of the aperture. The cells are nearly half as long again as in *Cellaria*

Schreibersi, Rss., with which Mr. Woods compares it; and, further, the two prominent avicularia are wanting; but from my Val-di-Lonte specimens of *C. Schreibersi* I find that both belong to the Schizoporellidæ, and are allied in many particulars.

Loc. Muddy creek, Western Victoria (*W.*).

64. Retepora marsupiata, Smitt. Plate XV. figs. 34, 35, 36; Plate XVII. figs. 59, 61, 76, 77.

Retepora marsupiata, Sm. Floridan Bry. p. 67, pl. xiii. figs. 245–254; Svenska Vetensk. Handlingar, vol. xi. 1872.

Phidolophora labiata, Gabb & Horn, " Polyzoa of Second. and Tert. Form. of N. Amer." p. 138, pl. xix. fig. 21 (Journ. Ac. Nat. Sci. Philad. vol. v. pt. ii.).

Zoarium reticulate. Zoœcia suboval to hexagonal, separated by a distinct raised border; peristome elevated in young cells; in old ones the aperture is immersed, with sometimes a spine on each side of the aperture; in front of the peristome a ridge, at the base of which is sometimes a small pore (sometimes avicularian); this gives a distinctly sinuated appearance to the peristome: in some specimens large, erect, angular avicularia in the middle of the zoœcium; in others large erect more spathulate avicularia; in others very long and very narrow immersed avicularia in a similar position, with the mandible in all cases pointing directly or diagonally downwards; sometimes there are small rounded avicularia pointing downwards, with a central pore. Surface smooth, or with few granulations; often two large pores near the proximal extremity of the zoœcia. One ovicell is subimmersed, with one cleft, as described by Smitt; another is more raised and more globose, with two depressed lines close together instead of the one central cleft; and there is also a small boss on the centre of the ovicell. The dorsal surface, which is divided irregularly by thin raised lines, has minute rounded avicularia scattered about; there are also long, triangular, immersed avicularia and large erect ones. In the basal portion the aperture is depressed, when we find the structure figured in figs. 59, 61, and 76, which are drawn from different specimens; but intermediate ones leave little doubt as to their identity.

In these we see the median pore representing avicularia, and showing the relationship to *Porina*. Median pores are known in *Retepora tuberculata*, Rss. Some of the basal branches seem to show that reticulation was much less frequent than in most *Reteporæ*; and this and *R. rimata* would be *Psileschara* of Busk, a genus which cannot be retained.

It is impossible to be quite sure if this is the same as the fossil described by Gabb and Horn. It is evidently allied to *R. Beaniana*, King, and probably is the species described under that name by Stoliczka. The suboral pore represents the suboral avicularium in *R. Beaniana*; and small avicularia are found on the front of *Beaniana*.

Loc. Living: Floridan seas, 16–262 fathoms (*Sm.*); Teneriffe (*Busk*). Fossil: Miocene, S. Barbara, Amer. (*G. & H.*); Mount Gambier (*Lond. Geol. Soc. coll.*).

65. Retepora rimata, sp. nov. Plate XVI. figs. 48, 53.

Zoarium probably reticulate; branches slightly compressed. Zoœcia cylindrical, convex; surface smooth; peristome much raised, with a cleft in front the whole length of the peristome, expanding at the base, the edges on the two sides of the cleft turned inwards, peristome often surrounded in front with a raised rim. Small subimmersed avicularia below the peristome, subtriangular or suboval, pointing upwards, with a very minute opening near the distal end. Dorsal surface divided by white raised lines, with small, subcircular, acute avicularia and small bosses irregularly placed.

This is common from Mount Gambier; but the state of fossilization would not have permitted all the characters to be made out if the "Yarra-Yarra" specimens had not served as a key.

Loc. Fossil: Mt. Gambier (*Lond. Geol. Soc. and Eth., jun., coll.*).

In one specimen the avicularia in the front are replaced by a simple pore. This would unite the genus with Porinidæ; and we here see another example of the avicularia taking the position of pores, and are led to regard avicularia as modified pores.

66. Cellepora yarraensis, sp. nov.

Zoarium cylindrical, dividing dichotomously, in one case throwing out a branch forming an angle of about 80°; diameter of stem 1–2 millim. Zoœcia very irregularly arranged, placed sometimes very crowded, sometimes far apart, indistinct; peristome much raised on the lower or avicularium side, usually not at all on the other, giving it, when seen in profile, a triangular appearance; at the proximal part of the peristome an avicularium; when this is broken down the two large openings have the appearance so general in Celleporæ; between the zoœcia few large much raised perforated protuberances, probably sometimes avicularian. Surface smooth, porcellaneous. Oral aperture semicircular, rounded on the distal edge, straight on the proximal, though when raised cells are seen the aperture appears rounded. Aperture 0·08 millim. wide, 0·1 millim. long.

I have an undescribed thin branching species of *Cellepora* from Capri (near Naples) which also has the lower edge of the aperture straight and in many respects resembles the present.

67. Cellepora fossa, Hasw. Plate XVIII. fig. 89.

Sphæropora fossa, Haswell, "On some Polyzoa from the Queensland Coast," Proc. Linn. Soc. New S. Wales, vol. v. pt. i. 1880, p. 42, pl. iii. fig. 5, 6.

Zoarium subglobular, flattened above, specimens 2–5 millim. in diameter. On the upperside the zoœcia are directed from the pole of the zoarium; on the underside they are directed towards it. Zoœcia subcylindrical or ovate or conical, very finely granular, erect (on the upperside); a few pores round the edge of the zoœcium on the upperside, but seldom on the back. Oral aperture rounded on the distal wall, straight on the proximal. In the centre, immediately below the proximal margin, a large, wide, erect, obtusely conical or globular avicularium. Few large, spatulate, zoœcial avicularia scattered over the colony. Aperture 0·12 millim. wide, 0·1 millim. long.

I cannot attach any importance to the pit round which the zoœcia are formed and upon which Mr. Haswell's new genus is founded. The form of the oral aperture is rare in the Celleporidæ; but we see the same thing in *C. sardonica*, Waters ("Bry. Bay of Naples," Ann. Nat. Hist. 1879, p. 196), also in *C. yarraensis*, W., in *C. intermedia*, M'G., and in *C. compressa*, Busk, with which perhaps the above should be united; and perhaps these together should form a subgenus. This may be one of the *Celleporœ* described by Mr. Tenison Woods in "Tertiary Fossils in S. Australia," p. 5 (Trans. Roy. Soc. of Victoria, vol. vi.); but identification with these is impossible, as the zoarial instead of the zoœcial characters are described. In describing fossil Bryozoa so little attention has been paid to the most important character, *i. e.* the form of the oral aperture, that comparison is often not possible.

Loc. Living: Holborn Island, Queensland, 20 fathoms. Fossil: Mount Gambier (*Lond. Geol. Soc. and Eth., jun., coll.*).

68. Cellepora, sp.

There are a few cells of a *Cellepora* which resemble those of *C. pumicosa*, Busk (non Linn.); but the fragment is too small to determine with certainty.

69. Lunulites guineensis, Busk.

Cupularia guineensis, Busk, Cat. Mar. Polyz. p. 98, pl. cxiv.

The specimen in Miss Jelly's collection is very small; but as the few zoœcia correspond in shape with those figured by Mr. Busk, we may safely conclude that the same species is represented.

Loc. New Guinea (*B*).

70. Lunulites cancellata, Busk.

Lunulites cancellata, Busk, Cat. Mar. Pol. p. 101, pl. cxiii. figs. 4–7.

Loc. Philippine Islands (*Busk*); off Raton, New Guinea, 7 fathoms, and from Darnley Islands, Torres Straits, 10–30 fathoms (sent me by Mr. Brazier).

71. Selenaria marginata, T. Woods. Plate XVII. fig. 71.

Selenaria marginata, T. Woods, "On some recent and fossil Species of Australian Selenariadæ (Polyzoa)," Trans. Phil. Soc. Adelaide, 1880, p. 9, pl. ii. fig. 9, *a–d*.

The zoœcial cells are very small, and in shape resemble those drawn by Mr. Woods. In some of the zoœcia there is a plate, some little distance down the aperture, with a central perforation, so that the zoœcium is almost closed. Sometimes the same thing is seen in *Cellaria fistulosa* both recent and fossil. I hardly understand Mr. Woods's description or plate when he refers to the pore; but I think this is undoubtedly the species he describes. Aperture 0·06 millim. wide.

Loc. Living: Cape Three Points, 71 fathoms.

72. Selenaria alata, T. Woods.

Selenaria alata, Tenison Woods, "On some recent and fossil Species of Australian Selenariadæ (Polyzoa)," Trans. Phil. Soc. Adelaide, 1880, p. 11, pl. ii. fig. 12, *a*, *b*, *c*.

Loc. Muddy Creek, Miocene Beds near Hamilton, Victoria (W.).

The specimen is smaller than those described by Mr. Woods, only measuring 2½ millim.; but otherwise the differences are very small and do not seem sufficient to make it a variety. The specimen may be described as follows:—Zoarium small, orbicular, moderately convex. Zoœcia rhomboidal or semicircular, margins distinct; area depressed, aperture large, narrowed below by triangular alæ at each side. Avicularian areas few, not so large as the zoœcia. Under surface with radiating grooves.

All Mr. Woods's figures for the above memoir are drawn upside down, perhaps by an error of the lithographer; and Mr. Woods seems to have described his species from the figure when he says of the aperture "narrowed above" instead of "below."

Besides the specimens determined, there are several imperfect fragments of other species, among which there is a badly preserved *Lunulites* somewhat resembling *L. aperta*, T. Woods; and there are a few cells of a species (probably with *Lepralia* growth) with ventricose punctured cells and a long projecting spout below the aperture resembling that of *L. mamillata* (Crag Polyz. pl. vi. fig. 5 *c*), and a few zoœcia of an erect form with elongate subtubular coarsely punctured zoœcia with a projecting wide peristome; each zoœcium springs laterally from the one below, in the same manner as in *Cribrillina dentipora*, fig. 33.

EXPLANATION OF PLATES XIV.–XVIII.

Plate XIV.

Fig. 1. *Cellaria fistulosa*, L., $\frac{25}{1}$, showing openings for the horny connecting tubes.
2. —— ——, $\frac{25}{1}$, showing avicularia and ovicell.
3. —— *malvinensis*, Busk, $\frac{25}{1}$, showing avicularia.
4. —— *ovicellosa*, Stol., $\frac{25}{1}$.
5. Section of ditto.
6. Central walls of ditto, showing rosette-plates.
7. *Smittia centralis*, var. *lævigata*, nov.
8. Section of ditto, showing rosette-plates.
9. *Membranipora maorica*, Stol., $\frac{25}{1}$.
10, 11. *Cellaria fistulosa*, L., $\frac{25}{1}$.
12. *Cellaria* sp., $\frac{25}{1}$.
13. *Schizoporella vigilans*, sp. nov., $\frac{25}{1}$
14. *Membranipora lusoria*, sp. nov., $\frac{25}{1}$.
15. *Schizoporella australis*, T. Woods, $\frac{25}{1}$.
16. *Cellaria globulosa*, sp. nov. $\frac{25}{1}$.
17. End view of do.
18, 19. *Membranipora macrostoma*, Rss., $\frac{12}{1}$.
20, 21. —— *argus*, d'Orb., $\frac{12}{1}$: *a*, lateral rosette-plates.
22, 23. —— *concamerata*, sp. nov. $\frac{12}{1}$.

Plate XV.

Fig. 24. *Lepralia monilifera*, Rss., var. *armata*, $\frac{25}{1}$.
25. *Microporella coscinopora*, var. *armata*, $\frac{25}{1}$.
26. —— *violacea*, var. *fissa*, $\frac{25}{1}$.
27, 28. *Microporella yarraensis*, sp. nov., $\frac{25}{1}$.
29. *Microporella ænigmatica*, sp. nov., $\frac{25}{1}$.
30. —— ——, seen from the interior, showing cribriform plate.
31. *Schizoporella phymatopora*, Rss., $\frac{25}{1}$.
32. —— ——, inner surface of broken piece.
33. *Cribrillina dentipora*, in *Bactridium*-form, $\frac{25}{1}$.
34, 35, 36. *Retepora marsupiata*, Smitt, $\frac{25}{1}$.

Plate XVI.

37, 38. *Catenicella solida*, sp. nov., $\frac{25}{1}$.
39. *Catenicella cribriformis*, sp. nov., $\frac{25}{1}$.
40, 41. —— *flexuosa*, sp. nov., $\frac{25}{1}$.
42, 43. —— *elegans*, var. *Buskii*, $\frac{25}{1}$.
44, 45. —— *marginata*, sp. nov., $\frac{25}{1}$.
46. *Catenicella ampla*, sp. nov., $\frac{25}{1}$.
47. —— *alata*, Thom., $\frac{25}{1}$.
48. *Retepora rimata*, sp. nov., $\frac{25}{1}$.
49. *Catenicella alata*, Thom., $\frac{25}{1}$., dorsal surface.
50. —— *ampla*, sp. nov., dorsal surface, $\frac{25}{1}$.
51, 52. *Canda fossilis*, sp. nov., $\frac{25}{1}$.
53. *Retepora rimata*, sp. nov., dorsal surface, $\frac{25}{1}$.
54. *Mucronella duplicata*, sp. nov., $\frac{25}{1}$.
55. *Membranipora geminata*, sp. nov., $\frac{25}{1}$.
56. *Schizoporella excubans*, sp. nov., $\frac{25}{1}$.
57. *Porina coronata*, Rss., $\frac{25}{1}$.
58. *Catenicella alata*, Thom., $\frac{25}{1}$.

Plate XVII.

59. *Retepora marsupiata*, Smitt, $\frac{12}{1}$, basal portion.
60. *Lepralia corrugata*, sp. nov., $\frac{12}{1}$.
61. *Retepora marsupiata*, Smitt, $\frac{12}{1}$.
62. *Cellaria ovicellosa*, Stol., $\frac{25}{1}$.
63. *Microporella elevata*, T. Woods, $\frac{12}{1}$.
64. —— ——, seen from the interior, $\frac{12}{1}$.
65. *Smittia Tatei*, T. Woods, $\frac{25}{1}$.
66. *Mucronella mucronata*, Smitt, $\frac{12}{1}$.
67. *Porina clypeata*, sp. nov., $\frac{25}{1}$.
68. *Cribrillina terminata*, sp. nov., $\frac{12}{1}$.
69. *Porella emendata*, sp. nov., $\frac{12}{1}$.
70. —— *denticulata*, Stol., $\frac{12}{1}$.
71. *Selenaria marginata*, T. Woods, $\frac{25}{1}$.
72. *Microporella ferrea*, sp. nov., $\frac{12}{1}$.
73. —— *violacea*, var. *fissa*, seen from the interior, showing the elongate median pore, $\frac{25}{1}$: *a*, pore, $\frac{85}{1}$.
74. *Membranipora cylindriformis*, nov., $\frac{25}{1}$.
75. *Cribrillina suggerens*, sp. nov., $\frac{25}{1}$.
76. *Retepora marsupiata*, Smitt, $\frac{12}{1}$. Basal portion.
77. —— *marsupiata*, Smitt, $\frac{12}{1}$.

Plate XVIII.

78, 79, *Catenicella internodia*, sp. nov., $\frac{25}{1}$.
80. *Schizoporella excubans*, sp. nov., about $\frac{10}{1}$: *a*, aperture of ditto, $\frac{85}{1}$.
81. —— *conservata*, sp. nov., $\frac{25}{1}$.

Fig. 82. *Membranipora lusoria*, sp. nov., $\frac{25}{1}$.
83. *Microporella symmetrica*, sp. nov., $\frac{25}{1}$.
84. —— *clavata*, Stol., $\frac{25}{1}$.
85. *Schizoporella submersa*, sp. nov., $\frac{25}{1}$.
86. *Caberea rudis*?, Busk, $\frac{25}{1}$.
87. *Lepralia spatulata*, sp. nov., $\frac{12}{1}$.
88. *Porina columnata*, sp. nov., $\frac{12}{1}$.
89. *Cellepora fossa*, Hasw., $\frac{12}{1}$.
90. *Microporella elevata*, Woods, $\frac{12}{1}$: *a*, transverse section of growing end.
91. *Mucronella elegans*, MacG., $\frac{25}{1}$.
92. *Lepralia cleidostoma*, Sm., var. *rotunda*, nov., $\frac{50}{1}$.
93. *Retepora marsupiata*, Smitt, $\frac{12}{1}$.
94. *Smittia anceps*, MacG., $\frac{12}{1}$: *a*, oral aperture, $\frac{50}{1}$; *b*, aperture seen from the interior.

Discussion.

The President stated that the abstract read only gave the main points of a series of elaborate palæontological descriptions. In reply to Mr. Charlesworth, he said that Mr. Waters had settled the question between Ehrenberg's name of "Bryozoa" and Thompson's name of "Polyzoa" in favour of the former.

25. *On* Soilcap-Motion. By R. W. Coppinger, Esq., M.D. (Read March 23, 1881.)

(Communicated by the President.)

I wish to call attention briefly to a phenomenon which, so far as I am aware, exists to an unparalleled degree about the shores of Western Patagonia, and whose presence there is in a great measure due to the exceptionally wet nature of the climate. I allude to a slippage of the soilcap, which is, I believe, continually taking place over the basement rock wherever the latter presents a moderately inclined surface. Some of the effects of this soilcap-motion are apt to be confounded with those due to glacial action; for the soilcap takes with it in its progress not only its clothing of trees, ferns, and mosses, but also a "moraine profonde" of rocks, stones, stems of dead trees, peat and mud, whereby the hills of this region are being denuded, and the valleys, lakes, and channels, gradually filled up.

On arriving at the Patagonian archipelago my attention was directed to this subject on noticing that the lower branches of trees fringing the sea-shore were in many places withering from immersion in the salt water, and that in some cases entire trees had perished prematurely from their roots becoming entirely submerged. On looking more closely I observed that the sodden snags of dead timber, mingled with stones, were often to be seen at the bottom of the inshore waters, and that the beds of fresh-water lakes were plentifully strewn with similar fragments of wood, the remains of forests prematurely destroyed. As the soilcap, by its sliding motion, reaches the water, the soluble portions are removed; and just as stones and boulders are often seen deposited in grotesque situations by a melting iceberg or a receding glacier, so are the phenomena of "perched rocks" to be here observed, although, in the class of cases to which I refer, due to a totally different cause. These facts are all the more interesting from their occurring in a region where the effects of *old* glacial action are to be seen in a marked degree. Planings, scorings, striæ, and "roches moutonnées" may almost invariably be found wherever the rock is sufficiently capable of resisting the disintegrating influence of the weather to retain these impressions. Thus they are nowhere to be seen on the coarse-grained friable syenite, which is the common rock-formation of the district: but where this rock is intersected by dykes of the more durable greenstone, the above-mentioned signs of former glacial action may be seen well developed. There are therefore in this region ample opportunities of comparing and differentiating phenomena which have resulted from "glacial action" and those which are due to "soilcap-motion"—a force now in active operation.

I may here observe that we did not see any glaciers worthy of the name either on the western islands or abutting on the mainland shores of Patagonian channels, although they undoubtedly exist further eastward, and discharge icebergs at the head of some of the deep fiords. In the main straits of Magellan there are fine examples of complete and incomplete glaciers, where one may observe in all its grandeur the wonderful denuding power which these ponderous masses of ice exercise as they move silently along their rocky beds.

Sir Wyville Thomson (vide 'Voyage of the Challenger,' the "Atlantic," vol. ii. p. 245) attributes the celebrated "stone rivers" of the Falkland Islands to the transporting action of the soilcap, which, among other causes, derives its motion from expansion and contraction of the spongy mass, due to varying conditions of moisture and comparative dryness; and this hypothesis is to a certain extent supported by the occurrences which I am now endeavouring to describe. Here, in Western Patagonia, are evergreen forests, and a dense undergrowth of brushwood and mosses clothes the hillsides to a height of about 1000 feet; and this mass of vegetation, with its subjacent soil, resting as it frequently does upon a hillside already planed by ice-action, naturally tends, under the influence of gravitation, combined with that of expansion and contraction, to slide gradually downwards until it meets the sea or a lake or valley. In the first two cases its free edge is then removed by the action of the water, in a manner somewhat analogous to the wasting of the submerged snout of a Greenland glacier in the summer time; and in the last case the valley becomes converted into a deep morass.

It appears to me that the conditions which are said to have resulted in the production of the "stone rivers" of the Falklands here exist in equal if not greater force. There is the thick spongy vegetable mass covering the hillsides and acted on by varying conditions of extreme moisture and comparative dryness; there are the loose blocks of disintegrating syenite to be transported; and there are the mountain-torrents, lakes, and sea-channels to remove the soil. Of actual motion of the soilcap we have at least strong presumptive evidence; but nowhere in the valleys have I found any thing resembling a "stone river."

It might perhaps be thought that a slow and gradual depression of the land would account for some of the above phenomena; but I have seen no reliable sign whatever of *subsidence*, and have, on the contrary, the evidence of numerous raised beaches and the work of stone-boring mollusca at heights above the present sea-level to prove that *elevation* of the land has taken place.

The subject is one full of interest; and feeling confident that it will repay further investigation, I take this opportunity of bringing the foregoing observations to your notice.

Discussion.

The President said the theory brought forward in this paper would very well account for some cases of the infilling of valleys, lakes, and sea-margins, and was especially important as showing how some phenomena ordinarily attributed to ice could be produced.

Mr. Ussher asked what the nature of the subsoil was.

Mr. Fordham asked for information as to the origin of the soilcap, and its formation on the high ground from which it was stated to be slipping.

Mr. Hawkshaw remarked that engineers, to their cost, were well acquainted with the unstable condition of the soilcap. Small disturbances often set in motion large masses not only of clays but of rocks. Good examples of rock-movement might be seen on the Ripponden branch of the Lancashire and Yorkshire Railway. The surface once disturbed, continued to move for long periods. In some railway-cuttings the slopes had moved for twenty years.

Mr. Spratling called attention to the slipping of clay in the Brockley cutting, near new Cross.

Mr. Hudleston said this paper supplemented Sir Wyville Thomson's observations on the "stone rivers" of the Falkland Isles, where he explained the accumulation of quartzite blocks by this kind of slipping. Such observations tended to show how some of the old brec ciasmight have been formed by other agencies than that of ice.

26. *On the* PRECISE MODE *of* ACCUMULATION *and* DERIVATION *of the* MOEL-TRYFAN SHELLY DEPOSITS; *on the* DISCOVERY *of* SIMILAR HIGH-LEVEL DEPOSITS *along the* EASTERN SLOPES *of the* WELSH MOUNTAINS; *and on the* EXISTENCE *of* DRIFT-ZONES, *showing probable* VARIATIONS *in the* RATE *of* SUBMERGENCE. By D. MACKINTOSH, Esq., F.G.S. (Read April 27, 1881.)

CONTENTS.

I. INTRODUCTORY REMARKS ON THE VARIABLE CHARACTER OF THE LOWER BOULDER DRIFT OF THE LAKE DISTRICT, NORTH WALES, &c.

MANY years' observations along the east coast of the Irish Sea, from the Solway Frith southwards to the estuary of the Dee, have led me to conclude (as stated in former papers published in this Journal) that while the Upper Boulder-clay is a remarkably persistent and homogeneous formation, and while the line of separation between it and the cleanly washed, obliquely laminated, and boulderless sand and gravel (where the two formations are present) is always distinctly marked, the Lower Boulder formation varies both *vertically* and *horizontally* from compact stony clay to loam, gravel, and sand. This is more especially the case in the neighbourhood of the mountains and at comparatively high levels. Around the mountains of the Lake District (where it is called *pinnel*) it is often interstratified with or replaced by well-laminated and often contorted sand and gravel, as at Ulverston Railway station, between Ulverston and Arrad Foot, &c. In the neighbourhood of Bangor, though a stiff Boulder-clay may here and there be seen lying under stratified sand and gravel, the two kinds of drift may quite as often be found in *horizontal* succession; and they both agree in containing boulders (see VII. 1 and 2).

II. MOEL-TRYFAN DEPOSITS, &c.

1. *Brief History of Discovery.*—In 1871, and again in 1880 (last year), I had opportunities of tracing the drift-deposits of Caernarvonshire from the neighbourhood of Bangor to the top of Moel Tryfan, and of observing a number of facts connected with the Moel-

Tryfan deposits which would appear to have escaped the notice of previous observers. But before proceeding to the main subject, it may be desirable to give a brief account of the discoveries made since the first published account of the deposits.

Trimmer, in the 'Proceedings' of the Geological Society for 1831, has a short notice of the Moel-Tryfan drifts, in which he found *Buccinum*, *Venus*, *Natica*, and *Turbo* (if correctly identified) beneath 20 ft. of sand and gravel. In vol. i. of the 'Journ. of the Geological Soc. of Dublin' (1838), he wonders if the granite as well as the flints he found on Moel Tryfan came from Ireland. [He heard of quarrymen finding sea-shells on Moel Faban, near Bethesda, where Darwin afterwards could find no trace of drift likely to contain shells.] In his work on Geology, published in 1841, Trimmer gives a general section of the drift from Menai Strait over Moel Tryfan to Mynydd Mawr. He could find granite erratics only at eight points between Menai Strait and Snowdon.

Buckland, in 1841, found rounded chalk-flints and white granite in the Moel-Tryfan deposits. His paper was read before the Geological Society, and an abstract of it appeared in the 'Athenæum,' in 1842.

Darwin, in 1842, in the 'London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science,' gives a very suggestive description of the Moel-Tryfan deposits. He found boulders, chiefly from the neighbouring mountains, but likewise rounded flints and white granite. Under the drift he saw that the surface of the slate, *to a depth of several feet, had been shattered and contorted in a very peculiar manner.* He did not find shells; but near the summit of the hill, on the east side, he saw a thickness of at least 20 ft. of irregularly stratified gravel with *boulders* and layers of sand and fine clay. He attributed the shattering and contorting of the slates to *icebergs grating over the surface*, and lifted up and down by the tides. The shattered and rounded slate rocks were similar to what he had seen in Tierra del Fuego. He believed that the Chalk flints had been brought by *floating coast-ice.*

Darbishire gave an account of the Moel-Tryfan deposits in the 'Proc. of the Manchester Lit. and Phil. Soc.' for 1851–52, and in the 'Geol. Magazine,' vol. ii. He believed that a layer of yellowish-brown sandy clay 1 ft. 9 in. thick had preserved the shells in the underlying sand and gravel. He collected a great number of shells, a list of which may be found in Mr. Shone's paper in the 'Quart. Journ. Geol. Soc.' for May 1878, and in Dr. Gwyn Jeffreys's paper in the same Journal for Aug. 1880.

Lyell and Symonds, in 1863, visited Moel Tryfan, and found a mass of incoherent stratified sand and gravel, 35 ft. thick, with fragments of shells, and a few whole specimens. In the lower beds they saw several large boulders of far-transported rocks glacially polished and scratched on more sides than one.

Ramsay and Etheridge, in 1876, examined the Moel-Tryfan deposits, and found that the boulders were chiefly local, and that the sand and gravel were obliquely laminated, similar to what may be seen on a sea-beach. Ramsay gives a comprehensive account of the deposits in the last edition of his 'Physical Geography and Geology of Great Britain.' He specifies the indirectly local erratics which came under his notice, and regards the mountain from what may be called the Snowdon stand-point. Though he had previously observed the drift-sections (in 1852), it would appear that the curved slaty laminæ which I have been led to regard as the most interesting of all the Moel-Tryfan phenomena, were not during his visits, or indeed during the visits of any other geologist excepting Darwin, sufficiently striking to arrest attention, *In this paper the mountain will be principally regarded from the N.W. and N. stand-points.*

2. *Deposition during Submergence.*—It seems to be generally admitted that deposition is in excess during submergence, and denudation during emergence; and when we consider the thickness of and area covered by the Moel-Tryfan deposits, in connexion with the fact that they lie on a sloping surface, and reach up to within a short distance of the rocky crest of the hill, the idea of accumulation during the submergence or sinking of the land appears the most probable, while it is the most consistent with certain facts to be mentioned in the sequel.

3. *Identification of the Local and Erratic Stones.*—The most prevalent pebble, rock-fragment, or boulder in these deposits is a light-coloured felstone, which may have come from the Cambrian conglomerate of the upper part of the hill, or from adjacent hills. The fragments of talcose or chloritic schists must have come from rocks like those which are now found in the tunnel (near the top of the hill), or from similar rocks in the hills around Moel Tryfan. The basaltic-looking diorite or greenstone may have come from bands in the hill or adjacent hills. Many small quartz pebbles in the drift may have come from the Cambrian conglomerate already mentioned*. The numerous fragments of slate may be very nearly *in situ*, or may likewise have come from neighbouring hills. There are many Eskdale granite pebbles, and a smaller number of granite pebbles from the south of Scotland (chiefly Criffel). Chalk flints are rather numerous (during my last visit they predominated in a particular part of the excavation), and reach a height of about 1350 feet. Eskdale granite on Moel Tryfan is found up to at least 1350 feet above the sea, or 64 feet above the highest range of the rock *in situ*. Chalk-flints *in situ*, in Ireland, as Professor Hull has informed me, do not rise higher than about 1000 feet above the sea; so that on Moel Tryfan their height is 350 feet higher (see VIII.). On Moel Tryfan I found a pebble of red granite of unknown derivation, but exactly of the same kind as one I saw on the beach of West Cumberland, and one on the Blackpool beach.

4. *Arrangement of the Gravel and Sand.*—Most writers on the Moel-Tryfan deposits have noticed the extent to which the sand and fine gravel are obliquely laminated, and the resemblance they bear to what may be seen on a sea-beach. The sand is often as fine as

* I have to thank Dr. Hicks for assisting me in tracing the derivation of the local and indirectly local stones.

blown sand, and, when I last saw it, was in course of being blown by the wind, from the brink of the quarry-excavation, over the grassy flat above. On the right-hand side of the tunnel, where there is no clay above the sand, the latter presents a peculiarly involved appearance.

On the left-hand side of the tunnel (1880) the sand interlaminated with gravel had evidently been contorted to a great extent. The shell-fragments principally occurred in layers of fine gravel, in one place chiefly made up of angular flint chips. There the average thickness of the sand and gravel was about 10 feet, the clay above being about the same thickness. When Darbishire saw these drifts about thirty years ago the clay was only about 1 ft. 9 in. thick. In different quarry-excavations at different levels up the hill-side, sections more or less differing in their character have been revealed. In 1880 the brink of the drift-cliff was only about 30 feet below the base of the abruptly rising rocky crest of the hill; and it is more than probable that the crest once rose as an isolated mass of rock above the surface of the glacial sea. The shelly sand and gravel (so far as aneroids can be trusted) extend up to quite 1350 feet above the present sea-level; and they have been found as low down as 1170 feet.

5. *Position of Boulders.*—One may go for miles along a railway-cutting without seeing a single boulder *in situ*; but where a large clay- or gravel-pit has been excavated by the side of the railway, many boulders may be seen on the floor of the pit, the explanation being that boulders exposed in a railway-bank very soon tumble down and are covered up, blasted, or removed. It is therefore wrong to conclude that because there may be many boulders on the floor of a quarry in drift-covered rock, they were (as boulders) originally situated at the base or towards the base of the drift-deposits. It is probable that many of the boulders of the Moel-Tryfan deposits which now lie on the quarry floor, were once dispersed at various levels in the overlying drift; and in 1871 I saw a boulder at least 3 feet long high up in the sand. This accords with the fact that at lower levels, including Anglesey, very large boulders may sometimes be found imbedded in sand or fine gravel containing shell-fragments, as well as in clay.

6. *Bent and shattered Edges of Slaty Laminæ.*—In 1871 I noticed that the edges of the vertical slates were bent in the direction of Mynydd Mawr, or from about N.W. to S.E. Darwin, as already stated, observed somewhat similar phenomena in 1842, which he attributed to the impact of floating-ice. In 1880 I happened to see what may be called a magnificent display not only of the bending but likewise of the shattering of the edges of the slaty laminæ, and of the extreme contortion of the laminæ of sand by which the slates were covered (fig. 1). From the section (which from the quarry upper floor to the top of the clay is at least 20 feet thick) it is perfectly clear that the sand and overlying clay must have been deposited before the derangement of the clay, sand, and slaty laminæ took place. The only explanation which appears sufficient to account for this

derangement is the violent stranding of an iceberg or mass of floating ice from the N.W. on the previously accumulated clay, which it pressed forwards and downwards until it reached the sand, which it ploughed up and inverted, and then bent and shattered the edges of the slaty laminæ, so as to be able to roll up parcels of clay and slate-chips in the sand. The line marking the commencement of the slaty curvature is nearly horizontal; but the upper termination inclines slightly in the direction of the movement of the floating ice (at first probably raised a little above the level of flotation by the impact, and afterwards slightly lowered so as to regain its normal level). This section bears no real resemblance to some which are found in districts where traces of ice-action are absent, and which are believed by some geologists to have been caused by ordinary atmospheric action. On Moel Tryfan the finely laminated sand shows no trace of having ever been disturbed by the percolation of rain-water or by frost, while the preservation of the numerous shell-fragments in continuous though contorted layers of sand and fine gravel has evidently (as Darbishire long ago pointed out) been owing to the clay preventing the downward passage of rain-water. As Moel Tryfan is in the midst of a glaciated district, and as ice capable of bending the slates and contorting the sand must have brought the erratic stones, including chalk-flints from Ireland, why have recourse to any other supposition to account for the phenomena?

Fig. 1.—*Laminated Sand and Bent Slates on Moel Tryfan.*

A A, Slates; B B, Sand, with parcels of slate-chips and Boulder-clay; C C, Boulder-clay.

7. *Direction of Floating Ice in Ireland.*—According to the Rev. M. H. Close the principal direction of floating ice in Ireland during the glacial submergence was from about N.W. to S.E.; so that the local floating ice would only have to persevere in this direction, after leaving Ireland, in order to reach Moel Tryfan.

8. *Were all the Moel-Tryfan Shells brought by Floating Ice?*—This idea would appear to be untenable for the following reasons:—(1) The shells must at first have been somewhere *in situ*, and why not on Moel Tryfan? (2) The Mollusca may have lived where the erratic stones were imported as well as where they were exported.

(3) Shells have not been found in Eskdale on the old sea-coasts from which the granite erratics on Moel Tryfan were transported when the land was deeply submerged (see 11).

9. *Cause of the Absence of similar Deposits on the Lower Slopes of the Hill.*—It has often been remarked that beach-like deposits with shells have not been found on Moel Tryfan excepting towards the summit of the hill. It is perhaps too early to speak positively on this point, as there is a bare possibility of patches of such deposits being yet discovered. But the cutting for the railway above Bryn-gwyn, which extends from near the base to near the summit of the hill, shows no trace of laminated sand and rounded fine gravel, but, on the contrary, is everywhere a Boulder-clay or clayey loam, with stones, chiefly angular or subangular. The drift on the north side of the hill, so far as revealed by cart-roads, is somewhat similar to that above Bryn-gwyn, excepting towards the summit, where there are patches of gravel and sand interstratified with clay and loam. The cause of the difference in the deposits near the summit and lower down cannot (at least principally) be a difference in the sources of supply of the lower and higher drifts, because the materials for the elaboration of fine sand and gravel exist on the hill-slopes at low as well as at high levels. The most probable explanation seems to be that the submergence of the lower slopes of Moel Tryfan went on too rapidly to allow sufficient time for the accumulation of well-rounded beach shingle and sand (see sequel).

10. *Moel-Tryfan Shells and Erratics not pushed up hill by Land-ice.*—It has been asserted (though this is not the general opinion) that all the shells, along with the erratic stones, were pushed out of the bed of the Irish Sea as far south as Moel Tryfan, and then up the hill-slopes nearly to the summit by land-ice. But an intimate acquaintance with the character of the Moel-Tryfan deposits precludes this idea; for, if it were a true explanation, the shells and erratic stones would have diminished in number the higher up they were pushed. But, on the contrary, the shells and erratics in the drifts near the sea are fewer in number than on Moel Tryfan. This theory would likewise require to invest the land-ice with the power of rounding the pebbles derived from the upper part of the hill, and laminating the sand and fine gravel; for it ought to be remembered that though the sand and gravel are, in places, much contorted on Moel Tryfan, the contortion was evidently, in many instances, produced *after* their accumulation.

11. *Shells found by the Author.*—As my main object was not to look for shells, only the following nine species were named for me by Dr. Gwyn Jeffreys out of a number of fragments I collected :—

Cardium echinatum.	Tellina balthica.
—— edule.	Mactra solida, var. elliptica.
Cyprina islandica.	Saxicava rugosa.
Astarte sulcata.	Purpura lapillus.
—— borealis.	

It is quite consistent with the remark made in section 8, that some of the Moel-Tryfan shells may have been brought along with erratic stones from a distance by floating ice, provided we admit that Moel Tryfan may have returned the compliment; and a number of shell fragments which I found along with small flint chips certainly looked as if both had been brought and deposited at the same time, though their final juxtaposition in the lamina to which (in that part of the section) they were limited must evidently have been the result of rearrangement on the spot.

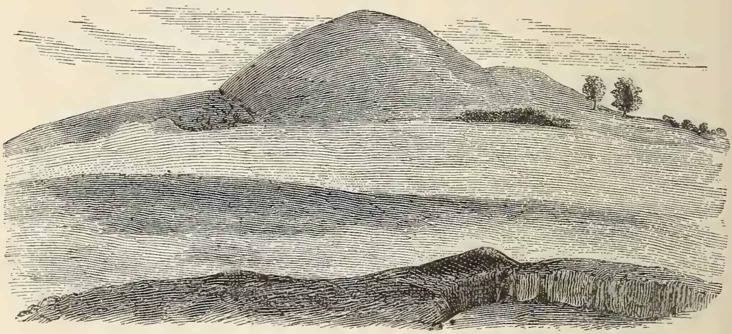
12. *High-level Gravel and Sand in other parts of Caernarvonshire.*—Near the summit-level of the pass of Llanberis, some years ago, I saw a striking section of obliquely laminated sand and fine gravel, probably about 1000 feet above the sea-level. The extent to which the stones were rounded, the arrangement of the laminæ, and the position of the deposit (being away from any channel which could have conducted a freshwater stream), all pointed to its being of marine origin, though I did not see any shells. Above Bethesda, near a farm-house marked Gwaun-y-gwiail on the Ordnance map (probably about 1000 feet above the sea), a gravel-pit shows laminated and contorted gravel and sand, in which (for reasons which need not be stated) I had not time to look for shells; but Trimmer told Ramsay that he had found shells in that neighbourhood up to from 1000 to 1200 feet above the sea. It does not seem to be well known that Ramsay found shells in Boulder-clay on Fridd Bryn-mawr (west of Llanberis) at a height of about 1000 feet above the sea.

13. *High-level Gravel and Sand in Ireland.*—It may be necessary to complete this account of high-level marine drifts in the western part of Wales by adding a brief statement of what Close found on the Three-rock Mountain near Dublin (see Geol. Mag. vol. i. Decade ii. 1874). He collected shells from gravel-pits at 850 feet, 1000, 1100, and a little higher than 1200 feet above the sea. The Three-Rock Mountain consists of granite; but the stones composing the gravel were very nearly all limestone, which must have been brought by floating ice from the N.W. They were nearly all subangular; but the deposits partly consisted of clean stratified gravel and sand [showing the action of the sea on the spot?]. He believed that the shells were brought along with the stones by floating ice, because both were scratched. He found more or less clay above the shelly deposits, and was led to believe that the mountain must have been submerged up to 1760 feet. The Three-rook Mountain is related to Moel Tryfan by the altitude of its shelly drifts, and by the direction of the floating ice which brought its erratic stones.

III. Deposits on Halkin Mountain, Flintshire.

Several years ago I read an account of these deposits before the Chester Natural-Science Society. Since then they have been mapped by the Geological Surveyors. The mountain, including its westerly continuation as far as the Vale of Clwyd, is a plateau surrounded on *all sides* by lower ground, so as to render it certain that the mounds of gravel and sand on its summit could never have been accumulated by the action of fresh water flowing onto it from a higher level. The mounds range from about 750 to about 900 feet above the sea. The rounded stones they contain are chiefly local limestone and grit of Carboniferous age; but Eskdale granite and Lake-District felstone may be found in some places, and chalk flints may occasionally be seen. The most striking mounds in which excavations have exposed sections are one situated near Brynford (not far from Holywell) and another towards the S.E. end of the mountain. The latter is named Moel-y-Crio on the Ordnance map, and rises from the summit of a ridge about 950 feet above the sea, with ground falling all around it, except on one side, where for some distance it is nearly horizontal, and then falls to a lower level. It would appear to have been accumulated not so much by wave-action as by the piling agency of sea-currents while meeting or parting.

Fig. 2.—*Perched Gravel-mound on Halkin Mountain.*



The Halkin-Mountain deposits of gravel and sand occur at a lower level than the other high-level marine drifts described in this paper; and they are not very distinctly separated (excepting, in most places, along the east side) from the low-level gravel and sand, which extends upwards from the sea-coast, and inland along the pass between Mold and Bodfari, which is traversed by the Chester and Denbigh Railway. Exceedingly few shell-fragments have been found in the gravel and sand of Halkin Mountain; but its comparatively flat summit, in places surrounded by ridges, must have been very favourable to the accumulation of rock-fragments derived from the inner slopes of the ridges; while it is easy to understand that these fragments, instead of being washed down the mountain-sides into deep water, would remain for a considerable time at the mercy of sea-waves, so as to become more or less rounded and smoothed by attrition. It ought likewise to be remembered that the mountain, while an island, must have been exposed all round its coasts to winds, which, by increasing the power of breakers, may have expedited the process of rounding stones; so that in the case of the summit of this mountain (which is situated at a lower level than that of the gravel and sand on Moel Tryfan, Frondeg, Macclesfield Forest, &c.) it is not necessary to suppose that the land subsided more slowly than at the levels immediately below and above, so as to afford more time for elaborating rounded gravel and sand. As already hinted, the scarcity of shell-fragments accords with the idea that the rate of submergence was not sufficiently slow to allow much time for the growth and accumulation of Mollusca. It ought likewise to be stated that on many parts of the mountain the stones in the gravel-beds are not much rounded.

IV. Discovery of High-level Deposits of Gravel and Sand between Minera and Llangollen Vale, Denbighshire.

For a long time, while travelling by railway between Wrexham and Ruabon, I fancied, from the surface-configuration of the eastern or outer slope of the range of mountains between Minera and Llangollen vale, that marine gravel might there be found at about the same height as on Moel Tryfan; but, being then bent on finding sea-shells at higher levels than the Moel-Tryfan deposits, I did not explore the district until near the close of last year (1880). From the railway, for some distance westward, the ground is flat or gently undulating, with an average elevation of between 300 and 500 feet. In many places sand may be found under a deposit which is horizontally continuons with the upper Boulder-clay of Cheshire; and here and there the sand, graduating into gravel, rises in the form of mounds or knolls. From the commencement of the gradual rise of the ground in a westerly direction up to about 1000 feet the prevailing drift is a clay or loam, with angular stones and large Carboniferous-grit boulders from the mountain-range above mentioned. At about 1000 feet the ground rather suddenly rises, and the stones (as may be seen in ploughed fields &c.) become more or less rounded. A little west of Braich, in the district called Frondeg (see 1-inch Ordnance map), the ground abruptly swells into a series of ridges and hillocks, which consist of well-rounded gravel and sand.

1. *Surface-configuration and Character of the Deposits.*—In the Frondeg district the gravel and sand knolls, with intervening or adjacent deposits of a similar character, extend for about a mile and a half from north to south, and about one third of a mile in breadth from east to west; but as similar accumulations are repeated at intervals as far south as Mountain Lodge, the whole length of the deposits may be about three miles—that is, supposing they extend no further south. On walking from Braich to the summit of the mountain-range in a westerly direction, after passing the gravel mounds, the surface becomes very flat and covered with peat. The breadth of the flat (which in some places extends, with a very gentle ascent, as far as the summit of the ridge, in other places not quite so far) is about half a mile. So far as can be seen in brook-channels, the peat overlies a deposit of clay with angular stones and large angular

boulders. The summit of the ridge varies from about 1450 feet to about 1500 feet. The well-rounded gravel-and-sand commences about 1100 feet (west of Braich), and extends in a westerly direction up to about 1350 feet. The hillocks (west of Braich), in one of which I found numerous shell-fragments in a gravel-pit, range in height from about 1100 feet to about 1250 feet. Above Mountain Lodge (S. of Frondeg) there is a gravel-pit in a knoll about 1200 feet above the sea, and one further west (in which I found shell-fragments) about 1230 feet. But the plateau, near the south edge of which these pits are situated, consists of rounded gravel-and-sand, which, in a westerly direction, rises to at least 1350 feet above the level of the sea*. In the gravel-pits and in the neighbourhood where sections are exposed in brook-channels, the stones, especially in the Frondeg district, are very much rounded, more so, in fact, than on the shores of the Irish Sea, where many of the stones (being derived from drift-deposits) have undergone a double process of rounding. This is the case especially with the Eskdale-granite pebbles, which, in the Frondeg gravel-pit, are almost as numerous as the local pebbles of Carboniferous grit or sandstone. In addition to these, there are chalk-flints, pebbles of Lake-district felstone and felspathic breccia, and local pebbles or fragments of Carboniferous limestone, with much decomposing coal and many coal-measure fossils, which can be best accounted for by supposing them to have been locally worked up from strata now concealed under the drift-deposits. In the Mountain-Lodge gravel-pits there are many Carboniferous-limestone fossils, and much granite.

2. *Shell-fragments.*—In the Frondeg gravel-pit shell-fragments are very numerous, but I could find no whole specimens. This can readily be explained by supposing that the excessive attrition to which the extra-rounded pebbles were subjected must have extended to the shells which were thrown up on the sea-beach. Among the fragments I collected from the Frondeg gravel-pit, and partly from one of the Mountain-Lodge gravel-pits, Dr. Gwyn Jeffreys has identified the following species :—

Cardium echinatum, *Linné.*	Tellina balthica, *L.*
C. edule, *L.*	Mactra solida, *L.*
Cyprina islandica, *L.*	Mya truncata, *L.*
Astarte borealis, *Chemnitz.*	Fusus antiquus, *L.*

3. *Position of Boulders.*—So far as can be seen in the gravel-pits and brook-sections, the large angular boulders are chiefly to be found in the clay, which extends under peat, from the west border of the gravel-hillock zone up to near or (in some places) quite to the summit of the mountain-range. They are likewise found, sometimes thickly strewn, on the *surface* of the clay, and to a less extent on the surface of large mounds, which partly, at least, consist of rounded gravel. They may also be seen scattered over the lower country as far east at least as the railway. In the Frondeg

* I have to thank the Director of the Ordnance Survey, Southampton, for some of the above heights.

district, where they consist of Carboniferous grit or sandstone (and partly of quartzose conglomerate), many of them must have been floated in an easterly direction from near the summit of the mountain-range after the submergence had reached that altitude; for how otherwise can their position on the *surface* of the drift-deposits be explained?

4. *Junction of the Arenig-felstone and Eskdale-granite Dispersions.*—West of Frondeg, on the summit-level of the mountain-range, about 1500 feet above the sea, and extending a short distance eastwards, the stones, with the exception of those of local derivation, consist of Arenig felstone; and large boulders of the same felstone are found on or near to the summit of the range further south, as well as strewn over the whole district between there and the Great Arenig mountain. I was surprised to find so great a number of Arenig pebbles on the ridge west of Frondeg, and equally surprised to discover that they abruptly terminated in an easterly direction not far from the water-parting, where their place (with very little dovetailing) was taken by Eskdale granite, reaching up to about 1400 feet. I arrived at the conclusion that there the northern-drift current which floated the Eskdale erratics was sufficiently powerful to turn aside the current by which the Arenig erratics were floated from the west. I cannot believe that the latter could have been brought by land-ice, because it appears improbable, if not impossible, that land-ice proceeding from the Arenig mountain could have attained a surface-level of 1500 feet (above the present sea) by the time it reached the ridge west of Frondeg; and it may likewise be remarked that as Arenig erratics have been found, not far from this ridge, on Cyrn-y-brain up to a height of 1830 feet, the supposed land-ice which brought them must have reached as high as that level, while further S.W., on Moel Gamelin, it must have reached to about 1900 feet*. This is about the limit reached by the glacial submergence in the N.W. part of Wales, where (as well as in the Frondeg district) the upward termination of the zone of rounded gravel-and-sand may be explained by an increased rapidity in the rate of submergence having deprived the sea of the time required to round stones by a process of combined rolling and attrition †.

5. *Frondeg Erratic Stones and Shells not transported by Land-*

* See my paper on the Boulders of North Wales in Quart. Journ. Geol. Soc. vol. xxx. (1874), p. 711.

† Mr. S. V. Wood, F.G.S., has written to me to the effect that he regards the discoveries I made in the Frondeg district as corroborating the conclusion at which he arrived after reading my paper on boulders (Quart. Journ. Geol. Soc. vol. xxxv. (1879), p. 425), namely that land-ice extended from the Arenig mountain to the top of the ridge west of Frondeg, on which it left the Arenig erratics; while floating ice from the Lake District brought the Eskdale erratics to the edge of the land-ice which prevented them from reaching further west, at the time when the submergence culminated at about 1400 feet. Mr. Wood likewise believes that the land-ice of the central part of North Wales spread out towards the N.E. and north, so as to prevent the erratics brought by floating ice from the north from getting into the interior of the country.

ice.—The idea of the granite pebbles of the Frondeg district having been brought by land-ice is opposed by the fact that few Eskdale-granite pebbles (so far as I have noticed) are to be found between Frondeg and the estuary of the Dee (the direction in which the ice would most probably move) excepting near the Dee estuary. There is likewise an equal absence of shell-fragments in the drift-deposits where the latter are present; but it is a remarkable fact that a great part of the area intervening between Frondeg and the Dee estuary is free from drift. Supposing the erratics and shells to have been pushed forward under the ice, they ought to be represented over the whole, or at least the greater part, of the intervening area, while no one would suppose that the numerous extra-rounded pebbles of Frondeg could have come in the form of a supraglacial moraine.

6. *Probable Decrease in the Rate of Submergence.*—It has already been remarked that from about 500 feet to about 1000 feet on the east side and flanks of the mountain-range under consideration the stones in the drift are generally angular or subangular, while above 1000 feet they are generally rounded, and in many places extra-rounded. It is likewise true that of the standard Frondeg erratics, namely Eskdale-granite, not one in fifty can be found in the comparatively low-level drifts between the mountain-range and the railway, while in the Frondeg district, above 1000 feet, Eskdale-granite pebbles are very numerous. We have no reason for supposing that the sea in this latitude was sufficiently warm to melt the floating ice, so as to cause the precipitation of many erratic stones. On the contrary, the great number of granite pebbles which have found their way as far south as Shrewsbury (where they are rather numerous in the lower Boulder-gravel, though not in the upper clay), and the much greater number (within a limited breadth of area) which reached as far south as Burton (S.W. of Broseley)* would seem to indicate that where many of these pebbles are found crowded in a small compass (as in the Frondeg district) they were left by the stranding and consequent breaking-up of floating ice. At this period the district was probably in the condition of a littoral zone, which may have lasted for a time sufficient to enable the waves to round the stones and to allow the Mollusca to multiply in the littoral and sublittoral zones, and thereby furnish many shells destined to be reduced to fragments by the rolling and grinding of stones on a much-exposed sea-coast. But a protracted sojourn of sea-waves in what is now the Frondeg district is likewise indicated by the time required for the accumulation of the immense number of erratic stones. That these stones were rounded approximately *in situ* is evident from the fact that at the high levels in the Eskdale district, from which the stones must have been launched, the stones are all more or less angular.

* See Quart. Journ. Geol. Soc. vol. xxxv. (1879), p. 425. The Frondeg erratics are not mentioned in this paper, as I had not discovered them when the paper was written.

V.—High-level Gravel and Sand near Llangollen.

Around Llangollen and elsewhere in North Wales a kind of loamy clay, or clayey wash, often forms the surface of the ground, and conceals what lies underneath. It may have been partly deposited as the land sank into deeper water, and partly during the rising of the land. The existence of an unknown extent of gravel and sand under this clay at a high level might never have been discovered but for the excavation of a pit a short distance east of Rhos Pengwern farm, in a field nearly 1200 feet above the sea-level. Under about 3 feet of clay, with perfectly angular stones, there is an unknown thickness of fine and coarse gravel and sand arranged in laminæ more or less arch-shaped. The stones are considerably rounded and smoothed, though the sand does not appear to have been very cleanly washed. There can, however, be no doubt about its being a sea-coast or shallow-sea deposit (though I could not find any shell-fragments), as its situation precludes the idea of its having been accumulated by any freshwater stream. More extensive excavations are required to show both its horizontal and vertical extent. At lower levels down to about 500 feet or 400 feet above the sea the drift contains scarcely any rounded stones, while it is particularly worthy of remark that in a pit at the east end of Grouse-box Hill (not far from Pengwern pit) about 1300 feet above the sea, the gravel is perfectly angular, and continues so up to the summit of the hill, 1715 feet above the sea.

VI.—Remarks on the High-level Gravel and Sand of Macclesfield Forest.

The identity in level of the Frondeg and Macclesfield-Forest deposits renders it appropriate that some notice should be taken of the latter. They were discovered by Professor Prestwich in 1862, near the Setter Dog Inn, at an altitude between 1100 and 1200 feet above the sea. He found more or less clay both below and above the shelly gravel and sand; but I should be inclined to regard the clay above as on a horizon distinct from that of the upper Boulder-clay of the plain of Cheshire, and more or less allied to the patches of clay or loam which overlie the high-level gravel and sand of North Wales. I found the shelly gravel near the Setter Dog Inn graduating eastward and upward, in the direction of Shining Tor, into angular gravel at a height of more than 1350 feet above the sea. At a greater height, in an easterly direction, all the gravel is angular; but S.E. of the Setter Dog, in Chapel Lane, rounded erratics may be found up to about 1400 feet. From these facts it would appear that the two gravel districts, the one on the west (Frondeg), and the other on the east (Macclesfield Forest), correspond almost exactly in level.—Near Clulow Cross, some distance south of Macclesfield Forest, Mr. Sainter (of Macclesfield) has discovered gravel and sand with sea-shells about 1130 feet above the sea (see his interesting work entitled 'Rambles round Macclesfield').

So far as I can recollect, the western slopes of the Penine hills between the above-mentioned levels and the plain of Cheshire are comparatively, if not entirely, free from rounded gravel; but I hope to have an early opportunity of speaking with certainty on this subject.

VII.—Arrangement of the Drift-deposits of North Wales into Vertical Zones, showing probable Variations in the Rate of Submergence.

The existence of the above rounded gravel- and sand-deposits, with shells, at about the same level in different parts of North Wales, and likewise in England and Ireland, could scarcely have been the result of accident. At a somewhat lower level than these deposits the drifts are angular, with a few exceptions, which may have arisen from local conditions having been unusually favourable to the rounding of stones by rolling and attrition. Above the level of the shelly deposits rounded gravel and sand with shells would appear to be everywhere absent. If the time required for rounding stones be viewed in connexion with that necessary for the migration and multiplication of Mollusca (as already remarked), it will not appear too fanciful to suppose that the rate of submergence was slower (probably much slower) in what may be called the rounded gravel and shelly zone than in the zones above and below, especially as it is *a priori* improbable that the submergence (up to at least 1350 feet above the present sea-level) progressed at a uniform rate. Many believe that the submergence terminated at the upper limit of this zone; but, as long ago advocated by Professor Ramsay, and recently repeated in his 'Physical Geography and Geology of Great Britain,' a clay similar to that in which he found shells west of Llanberis may be seen rising to a height of from 1500 feet to 1800 feet about the Turbary, and east of the river Ogwen. I noticed that the drift between the Turbary and the final ascent to Marchllyn Mawr (about 1700 feet) consisted either of clay or small chips and fragments arranged in a manner which could not possibly be explained by the action of fresh water; and in a continuation of this drift at a lower level the late Mr. Griffith Ellis, of Llanberis, told me he had discovered sea-shells. In the basins of the Llafar and Caseg (S.E. of Bethesda) the general surface-configuration of the ground up to about 1900 feet can be more easily explained by the former action of the sea than by freshwater agency; and this accords with the height reached by the Arenig boulder-dispersion in the nighbourhood of Llangollen (1897 feet on Moel Gamelin) and on the neighbouring hill-sides. In the present state of discovery it may therefore be said that the glacial submergence certainly reached an altitude of about 1350 feet (the extreme height at which sea-shells have been found), and very probably culminated at about 1900 feet. Below the middle (or Moel-Tryfan, Frondeg, and Macclesfield-Forest) zone of rounded and shelly gravel and sand, as already stated, there would appear to be a zone consisting of loam, with angular or subangular stones and no shells; but this zone is not uniformly continuous, as on Halkin Mountain (Sec. III.), and possibly in other places; it is varied by accumulations of more or less rounded gravel and sand. Below the third zone (order descending), and extending down to the existing sea-level, there is a zone of horizontally alternating clay, and angular and rounded gravel and sand, with boulders and shells*.

Causes of the horizontal Discontinuity of the Middle Zone of rounded Gravel and Sand.—The question may naturally be asked, How is it that the rounded and shelly drift of Moel Tryfan, Frondeg, and Macclesfield Forest are horizontally separated by areas in which the drift is angular? We may, I think, be enabled to arrive at some explanation of this fact by supposing that rounded drift on this horizon may exist in many places under a covering of Boulder-clay, which may have been wholly or partly left during the rising of the land; but there are other considerations which might account for the local absence of rounded drift, one of them being that the sea, by merely lingering for a time near the same level, might not be able to accumulate rounded drift without being assisted by other favourable circumstances or conditions (positive or negative) such as the following:—(1) a sea-coast exposed to wave-producing winds; (2) the previous or contemporaneous accumulation of heaps of angular débris by melting or stranding icebergs or coast-ice, frost, rain, gravitation, &c.; (3) the *absence* of steep slopes which would so facilitate the washing-down of preexisting angular débris below the reach of wave-action as to prevent the accumulation of rounded stones†; (4) the *absence* on sea-beaches of clay, which would be unfavourable to the rolling of stones; (5) the prevalence of stones susceptible of being easily rounded; (6) the existence of rapid currents capable of rolling stones below the limit of wave-action; (7) the preservation of relative levels of the differently characterized zones during the emergence of the land; (8) the non-alteration of the character of the zones by deposits left during *emergence*; (9) the non-removal of preexisting rounded gravel and sand from valleys and slopes by glaciers during or after emergence. The last consideration is very important; for, according to Professor Ramsay (to the great accuracy of whose observations in North Wales I can bear humble testimony), the marine drift of the northern valleys was ploughed out by the second glaciation of the country.

* It might unnecessarily complicate the main subject of this paper were I to refer particularly to a zone of fine rounded gravel and sand, with *no boulders*, at a low level in the plain of Cheshire and part of Lancashire (which I believe was deposited during the last stage in the *rising* of the land), or to the upper Boulder-clay at comparatively low levels, which I believe was the result of a *re-submergence* of the land. I lately found proofs of a *land-surface* between the upper Boulder-clay and underlying boulderless sand in excavations under Crewe railway-station, an account of which will soon be published.

† On the very steep slope of Mynydd Mawr, which is nearly opposite to the marine drift on Moel Tryfan, the stones are all angular.

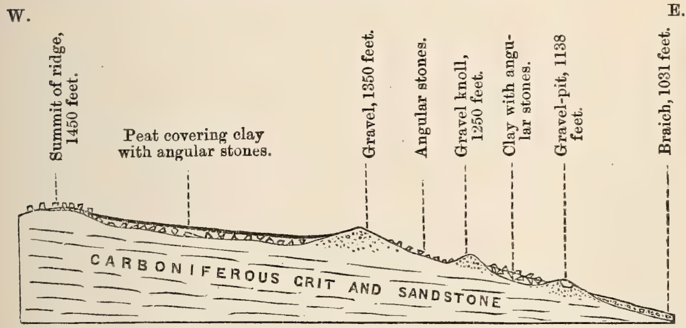
VIII.—Concluding Remarks as to whether the Submergence was caused by the Subsidence of the Land or Rising of the Sea.

In favour of the extension to the district under notice of Dr. Croll's theory of a rise of the sea-level by the melting of circumpolar ice, and consequent displacement of the earth's centre of gravity, and subsequent fall of the sea to its present level, it might be argued that this theory would most readily explain the coincidence in level between the marine drifts of Macclesfield Forest, Frondeg, Moel Tryfan, and the Three-Rock Mountain, especially when we take into account the great distance between the first- and last-named localities, and the comparatively very small vertical distance between the highest known shelly drifts and the present sea-level (about 700 to 1). It would likewise account for variations in the rate of submergence, by attributing the variations to changes in the rate of circumpolar liquidation, resulting from changes in temperature. Against the application of this theory to the district under consideration, we must take into account the differences in level between different parts of the land as it stood when the above marine drifts were deposited, and as it now stands. These differences would seem to indicate *horizontal inequalities* in the rate at which the land emerged, as might be expected on considering the extent of the submerged area. Thus the level of the greatest height reached by the chalk in Ireland (as Professor Hull tells me) nowhere exceeds 900 feet or 1000 feet. But at the time when chalk flints were transported to Moel Tryfan the chalk in Ireland must have reached to about 1350 feet above the present sea-level. The greatest height to which Eskdale granite extends is 1286 feet; but at the time when when this granite was transported to Frondeg, it must, *in situ*, have reached to at least 1400 feet. I have ventured to make these few brief remarks in conclusion with the view of stimulating to further inquiry on the subject, and partly because I have reason to believe that so eminent an authority as Dr. Darwin is now inclined to the opinion that many of the apparent changes of level in the land were caused by changes of level in the sea.

SUPPLEMENTARY NOTES.

During the present month (April, 1881), having gone over the ground described in this paper a fourth time, I am able to furnish the following additional details:—On going south along the west side of the axial north-and-south ridge of Minera mountain, I saw numerous large and small angular stones (Carboniferous grit, sandstone, and quartzose conglomerate); but I could find few or no rounded stones, excepting among the felstone erratics, which must have come from the west. After crossing the ridge and going in a S.E. direction down the eastern slope of the mountain, I arrived at a point nearly half a mile north of Erwau. Here it may be necessary to remark that though rounded stones in drift may often be seen in brook-channels and on roadsides, where the ground is flat, I have not examined any hillock or small mound which did not show signs of its being composed of rounded gravel and sand. Besides the four hillocks with gravel-pits (in one of which I found shell-fragments) near Mountain Lodge, during my last visit I counted ten which evidently consisted of drifts similar to deposits on our present sea-coasts. North of a brook which joins another brook near Erwau, I saw three rather low mounds with surface-excavations sufficient to show that they consisted of rounded gravel and stratified sand. The furthest north of the mounds was quite 1300 feet above the sea-level. While continuing my journey in a northerly direction, I saw many well-rounded stones in drift exposed in a brook-channel about 1350 feet above the sea. On descending towards a house called Braich (1031 feet above the sea, as I have been informed by

Fig. 3.—*Section of Drift-deposits between Braich and the Summit of the Ridge, Frondeg, Denbighshire.* (The levels, with the exception of the lowest and highest, are approximate.)



the Director of the Ordnance Survey), I encountered a knoll (fig. 3) about 1250 feet, showing the marks of a now disused gravel-pit, containing many rounded stones and sand. The shelly gravel-pit (described in the paper) lies between the above knoll and Braich. North of the latter there are three gravel hillocks between 1100 feet and 1150 feet. West of the house called Cae-mynydd there is a rather large hillock showing the remains of old gravel-pits. West and N.W. of it there are several large mounds (the highest nearly 1400 feet above the sea), the character of which is doubtful; but in one of them several small excavations show a mixture of rounded and angular gravel. A similar kind of drift may be traced nearly to the north end of the mountain. I had previously seen Eskdale granite only in the shape of small pebbles; but on this occasion I stumbled on two large blocks, one N.W. of Cae-mynydd, and the other associated with numerous millstone-grit blocks on the summit of the axial ridge (about a mile west of

Braich) at a height of about 1450 feet above the sea (fig. 3), which proved a submergence of the mountain to at least that extent.

During a fourth visit to the Mountain-Lodge district (above Ruabon) I found that higher up than the extensive area of rounded gravel there was an interval of angular detritus, above which (and near to the summit of the mountain-range) at a height of about 1550 feet, there was a mass of gravel as much rounded as that in which I found shells at a lower level. Gravel more or less rounded reappeared on the west side of the mountain at nearly the same height.

During a third visit to Moel Tryfan (June 1881) I found that several new sections had been exposed, in which a *close inspection* showed that the edges of the slaty laminæ were not *continuously* curved, though the broken-off chips were arranged along more or less curved lines which inclined from the N.W.

I ought to mention that, in the observations which have resulted in this paper, I was again assisted by the Committee of the Government Fund for Scientific Research.

Discussion.

The President, in inviting discussion, spoke of the great value of Mr. Mackintosh's paper.

Mr. DeRance spoke of the laborious manner in which Mr. Mackintosh had carried out his work, and thought that he had done much to refute the theory of a universal ice-cap overwhelming every thing. He said that he had examined some of the Molluscan fragments in Ireland, some of which were, indeed, scratched; but others, he thought, could only have been deposited during a submergence. He thought that the positive evidence in favour of submergence must overpower mere theory. As you ascend the slope of the Halkin mountain from the river Dee, you pass first over Glacial Drift containing erratics from the Lake district and south of Scotland; in the lower part a Boulder-clay resting on sands with Mollusca; but higher up the hill there is a different drift, local in character, and containing only North-Wales rocks.

Mr. Ussher inquired if the Moel-Tryfan deposit abutted against higher ground, as then the subaerial débris shed upon the beach might have been mixed with it, and a local reversal of laminæ produced by the impact of an iceberg.

Prof. Bonney said that he thought the facts brought forward by Mr. Mackintosh would give a death-blow to the idea that the Mollusca had been brought up hill by glaciers. He doubted, however, whether the creep of the mingled sand and clays down hill would not account for the bending of the slate-edges better than the grounding of an iceberg; for would not that bend them up hill? and how would it ground on the lee side of the hill? If terraces were formed by the rising of the sea due to a polar ice-cap, then they should not be uniform in level, but rise along circles of longitude towards the pole.

Dr. Hicks thought that no theory could be founded on the special direction of the slaty curvatures, as he had seen them in all directions. He asked if a glacier crossing Ireland along a north-west direction might not dam the sea up, so as to partially overwhelm Wales. He did not understand how the erratics could arrive at exactly the same points both from Ireland and the Solway.

Mr. Mackintosh, in reply, said that he thought that a grounding iceberg might, if raised first up hill, then slip slightly down hill, and so bend the edges of the slaty laminæ. To Dr. Hicks he replied that the currents in the sea were far from being necessarily parallel.

27. Upper Greensand *and* Chloritic Marl, Isle of Wight. By C. Parkinson, Esq., F.G.S. (Read March 23, 1881.)

Although the Isle-of-Wight Greensands have been well explored by eminent geologists, such as Fitton, Mantell, Ibbetson, and Saxby, there yet remains ample work for palæontologists in the classification of the fauna characteristic of each horizon. Hitherto the fossils from different zones have not been clearly separated, the collections from the Malm rock being mixed with those of the upper cherts and rags, and the Chloritic Marl with both. In forming a collection illustrative of the above series, it has been the writer's aim to divide every zone and to define the extent of each.

At the base of the section a band of chert nodules is indicated, measuring 2 feet, which is possibly the true junction of Gault and Greensand, although in the Memoir on the Geological Survey of the Isle of Wight 50 feet of micaceous sands below this point have been included in the Greensand; this has also been done more recently by Dr. C. Barrois, of Lille. It was from this section, exposed on the St.-Lawrence beach, that Captain Saxby procured a species of Crayfish; and a second specimen has been found within the last eighteen months in the same locality. The importance of this horizon has apparently been overlooked; for quite recently a further valuable addition has been made to the fauna by the discovery of a Chelonian previously unknown to palæontologists. From Captain Saxby's day to the present time the locality has been neglected. About a year ago Mr. Mark Norman, a well-known local geologist, noticed a huge boulder of this blue chert lying exposed to the wash of the tide; it had certain indications on the exterior which led him to examine the whole surface with care; there were, in fact, the perforations of bone clearly shown. With great care the hard matrix was chiselled out, revealing portions of the carapace and rib-bones of a Turtle of the family Paludinosa. The specimen is now in the Natural-History Museum, South Kensington; and through the courtesy of Prof. Owen I am enabled to give the following notes, abridged from a description kindly made by him. It is referred to the

Order CHELONIA.

Fam. Paludinosa.

Genus Plastremys, Owen.

Plastremys lata, Owen.

A new genus and species of freshwater Tortoise from the Isle-of-Wight Greensand, remarkable for its breadth in proportion to length. In this character it approaches nearest to the Tertiary *Emys lævis*; but the transverse dimension is not eked out, as in that species, by the accessory plastral plates, and the plastral portions of the marginal plates are respectively less broad in *Plastremys*, and allow a large relative proportion of the plastron to the under-surface of the portable dwelling.

The constituents of the plastron are in normal number, as in the typical Emydians; there are no accessory pieces interspersed between the hyo- and hypo-sternals, as in the Wealden genus *Pleurosternon.*

The precise measurements, together with figures and minute description, will be published shortly. In the meantime the fact of the discovery of a freshwater Tortoise in the Upper Greensand is of interest, throwing additional light on the conditions of life in that epoch, and involving either the proximity of a continent or the remains of island faunas distributed in the marine deposits.

The Crayfish obtained by Saxby, figured in Prof. Bell's Monograph of the Crustacea, and the Chelonian found more recently by Mr. Norman, evidently prove that more thorough investigations among these chert rocks might result in further important additions to the Greensand fauna.

The next 20 feet of compact red sand are for the most part unfossiliferous; or rather the organic remains have been nearly obliterated. It is harder in texture than the succeeding 4 feet. Without any other lithological change than hardness, we suddenly come to a zone in which well-preserved casts of Mollusca abound, differing, as will be noted, from the Upper Cherts and Rags in a remarkable manner. At the base of this (that is, 20 feet from the lowest chert nodules) an Ammonite occurs, which, so far as I can discover, has not been described. Two specimens found by Capt. Ibbetson are now in the Jermyn-Street Museum, unnamed; a third is now in the Natural-History Museum, South Kensington, in my Isle-of-Wight collection, recently purchased by the Museum authorities. It has been placed provisionally by Mr. Etheridge as a species between *A. auritus*, and *A. rostratus*; though I think it will be found to differ from both sufficiently to rank as a new species. It is invariably of the same size, from 2½ to 3 inches in diameter, and remarkably thin for its size, not having the prominent tubercles of *A. auritus* or the sharply defined chambers of *A. rostratus.* At the back the markings are alternate, more resembling the Gault species *A. interruptus.* Dr. Wright, of Cheltenham, was unable to identify my specimen with any species known to him.

Immediately above, though never intermixed, the following fossils are found:—

Ammonites auritus, *Sow.*
—— rostratus, *Sow.*
Trigonia aliformis, *Park.*
T. ornata, *D'Orb.*
—— vicaryana, *Lyc.*
Panopæa plicata, *Sow.*
—— mandibula, *D'Orb.*
Plicatula pectinoides, *Sow.*
Ostrea canaliculata, *D'Orb.*
Pecten orbicularis, *Sow.*
Cardium Gentianum, *Sow.*
Arca carinata, *Sow.*
Cucullæa glabra, *Park.*
—— fibrosa, *Sow.*
Natica sp.
Cinulia sp.
Vermicularia concava, *Sow.*
Rhynchonella latissima, *Dav.*
Terebratula biplicata, *Broch.*
Modiola sp.
Serpula antiquata, *Sow.*

And suddenly as this horizon appears, so it disappears, the succeeding 32 feet being identical with the sands below in lithological character, with the exception of being less hard and gradually getting lighter in colour as we follow it up the section. Organic remains are few and far between, *Holaster lævis* (on the authority of Dr. Wright, F.R.S.) being the only distinctive fossil. Up to this point the fauna may fairly be said to belong to the same epoch ; and collections from the lower division should be kept separate from those from the upper cherts and rags, which we now come to, and which indicate different conditions of life. The red sands give place to alternate bands of hard chert and coarse greensands (*vide* section). In the 6 feet of inferior building-stone *A. rostratus* attains its greatest development, and casts of large *Nautili* are common. This is divided from the building-freestone (which hardens on exposure to the atmosphere) by one foot of blue chert, having another chert band on the top little else but a mass of sponge-spicules imbedded in siliceous matrix. In the next bed of Greensand *Pecten orbicularis* is plentiful, though by no means confined to that band. *Pecten interstriatus* is not uncommon on the exposed surface of the succeeding Chert band, and species of *Lima* in other bands which could not be identified with certainty. The fossils may not all be confined to the various beds. *Pecten asper*, Lamk., never occurs in the Isle of Wight in these Cherts or Greensands ; it is confined to a bed of phosphatic nodules in the Chloritic Marl, but is probably derived from older rocks, being in most cases much crushed and broken.

The following fossils are from the Upper Chert and Rag beds :—

Siphonia pyriformis, *Park.*	Exogyra conica, *Sow.*
Nautilus elegans, *Sow.*	Ostrea frons, *Park.*
—— sp.	Lima aspera, *Sow.*
Lima, large sp., strong ribs.	Ostrea vesiculosa, *Sow.*
Pecten, 14 ribs, (Galliennei ?).	Cucullæa glabra, *Park.*
Cardium sp.	Pecten orbicularis, *Sow.*
Holaster sp.	—— interstriatus, *Lezon.*
Ammonites rostratus, *Sow.*	—— 5-costatus, *Sow.*
Clathraria Lyellii, *Mant.*	—— sp.

The Cycadeous plant *Clathraria Lyellii* was first noted by Mantell, who obtained his specimen from a quarryman in Bonchurch ; it was not obtained from the Chalk Marl, but from the Greensand Rags. A second specimen of this rare fossil was found at Steephill, near Ventnor, last winter, 10 feet below the Chloritic Marl, in the same bed as the former one. The remains consist of the top of the stem surrounded by petioles or leaf-stalks, the leaves themselves being either shed or decayed. It has usually been considered a plant of Wealden age. If, however, island floras and faunas can be shown to have existed during the formation of the Greensand strata, both Chelonia and remains of plant-life are at once accounted for.

The Chloritic or Glauconitic Marl, lying immediately over the Greensand, may be traced along the escarpment of the Undercliff, from Blackgang to Luccombe, cropping out finally near Culver Cliff. It varies in thickness from 6 to 7 feet, and may be divided into two beds, the lower $2\frac{1}{2}$ feet, with few fossils, divided by a layer of phosphatic nodules (with broken *Pecten asper*) from the upper $3\frac{1}{2}$ feet, which are rich in fossil remains. The best sections are at Ventnor-station quarries and below Old Park, St. Lawrence.

A. Fossils derived, in phosphate.

Ammonites varians, *Sow.*
Pleurotomaria sp.
Hamites sp.
A. curvatus, *Sow.*
Rynchonella Grasiana, *D'Orb.*
Solarium ornatum, *Sow.*
Pecten asper, *Lamk.*
Venus sp.
Cinulia sp.
Gibbula lævistriata, *Seel.*

B. Fossils slightly phosphatic.

Ammonites Coupei, *Brongn.*
—— varians, *Sow.*
—— Mantelli, *Sow.*
—— navicularis, *Mant.*
—— curvatus, *Mant.*
—— sp.
Hamites attenuatus, *Sow.*
Scaphites æqualis, *Sow.* (very rare).
Nautilus elegans, *Sow.*
—— expansus, *Sow.*
Turrilites Morrisii, *Sharpe.*
—— tuberculatus, *Bosc.*
—— Wiestii, *Sharpe.*
Emarginula sp.
Terebratulina striata, *Wahl.*
—— biplicata, *Sow.*
—— semiglobosa, *Sow.*
Plicatula pectinoides, *Sow.*
Rhynchonella Grasiana, *D'Orb.*
Pecten orbicularis, *Sow.*
—— Beaveri, *Sow.*
—— interstriatus, *Leym.*
Terebratula pectita, *Sow.*
Discoidea subuculus, *Leske.*
Micrabacia coronula, *Goldf.*
Cidaris vesiculosa, *Goldf.*
Vermicularia concava, *Sow.*

This Chloritic or Glauconitic Marl has caused considerable controversy as to its origin. I think the presence of phosphatic nodules between the two beds, together with crushed *Pecten asper* in great numbers, has not been sufficiently noticed. This would suggest a violent and sudden destruction in the phosphate bed, while in the upper $3\frac{1}{2}$ feet nearly all the Mollusca remain fairly perfect, and *Pecten asper* is not found.

Mr. A. J. Jukes-Browne suggested the name of "zone of *Scaphites æqualis*" for this marl; but as it is extremely rare to find a specimen of this *Scaphites* lower than the Chalk Marl, I would propose "zone of *Turrilites Morrisii*," which is peculiar to the Chloritic Marl.

The best sections and measurements of the Isle-of-Wight Upper Greensands were made as far back as 1849 by the late Capt. Ibbetson. These, together with measurements lately made by Dr. C. Barrois, of Lille, I prefix to my own section.

Capt. Ibbetson.

	ft.	in.
1. Zone of chert and rag with *P. orbicularis*, *P. 5-costatus* ...	15	0
2. Conglomerate of chert and rag	4	0
3. Chert and firestone	5	2
4. Freestone and layers of rag	11	6
5. Rag and malm	16	8
6. Mammillary rag, sandy boulders with phosphate of lime ..	1	6
7. Malm and rag	6	8
8. Fossiliferous malm	3	0
9. Malm and rag	40	0
	103	6

Dr. Barrois.

Zone			ft.	in.
P. asper.	E	Chloritic marl	8	0
	D	Greensand and chert	26	0
	C	Greensand, phosphatic nodules	6	6
A. inflatus.	B	Yellow sands with bands	13	0
	A	Micaceous, glauconite sands	117	0
			170	6

(The order of this section is reversed for uniformity.)

Section of Upper Greensand and Chloritic Marl, St. Lawrence and Ventnor, Isle of Wight.

	Chloritic marl 3½ feet (fossils list B, slightly phosphatic).
6 feet...	Hard phosphatic nodules, with crushed *Pecten asper.*
	2½ feet compact, darker grains: few fossils, mostly derived.
	Blue chert bands; casts of *Cardium* sp.
	Coarse greensand; casts of *Cucullæa glabra,* and *Holaster* sp. Chert.
24 feet...	Greensand: *Ostrea, Cucullæa, Arca.*
	Chert: *Lima* sp.
	Chert: *Pecten interstriatus.*
	Greensands: *P. orbicularis.*
	Chert with sponge-spicula imbedded.
	5 feet freestone, used for building-purposes: casts of *Nautilus pseudoelegans, N. elegans.*
	Chert, with phosphatic nodules.
14 feet...	6 feet inferior building-stone: casts of *Nautili.* *Amm. rostratus* here attains its greatest development.
	Blue chert.
	32 feet yellowish-red sandstones, varying in hardness. Organic remains few. *Holaster lævis* (on the authority of Dr. Wright).
	Zone of *Amm. inflatus,* Sow. *A. auritus, A. rostratus, Panopæa, Cucullæa, Arca, Trigonia.* About 4 feet.
56 feet...	Compact red sands.
	Species of *Ammonites* undetermined, between *A. rostratus* and *A. auritus.*
	Compact red rock, harder than the above, 20 feet, unfossiliferous.
2 feet...	Blue rag, fossiliferous. Astaciform Crustacea, Chelonia; passing into Gault sands.
102 feet...	

It will be found that the three measurements agree very nearly. Dr. Barrois includes the 50 feet of sands below the lowest two-foot bed of chert nodules, as has been done in the Geological Survey Memoir. In Dr. Barrois's hasty visit to the Isle of Wight, I think he inaccurately divided the zone of *P. asper* and *A. inflatus*, both of which are confined to extremely narrow limits. With regard to Capt. Ibbetson's measurements, I think the zone of fossiliferous malm is placed too high up; otherwise the section is very accurate.

In conclusion, I would call attention to the necessity for greater care in separating the fossils of each zone. Thus *Pecten asper*, *P.*

cretosus, *P. Beaveri*, *Lima* sp., *P. Galliennei* (?) may eventually be found to characterize different zones, while the entire fauna of the malm rock is different from that of the chert and rag beds.

I would propose, also, that the 50 feet of sands included in the Upper Greensand by Mr. Bristow, and more recently by Dr. Barrois, should be referred to the Gault, taking the well-marked band of chert boulders with Chelonia &c. as the true base of the Upper Greensand.

I also suggest, with some diffidence, that remains of island floras and faunas exist in the marine deposits of those Greensands, as evidenced by a freshwater Tortoise and Cycadeous plants, the former authoritatively stated by Prof. Owen to be a freshwater reptile, while the leaf-stalks and stems of tropical plants speak for themselves.

Dr. Barrois's division of the Upper Greensand into two zones is misleading, as the fossils are confined to such narrow limits. I would suggest, in place of this, several zones in the upper cherts identified by characteristic Pectinidæ, which are the best-preserved of the Mollusca, the fauna of the Malm rock being clearly separated from that of the Rag.

Mr. Jukes-Browne's zone of *Scaphites æqualis* is inaccurate. 20 feet higher up in the Chalk Marl *S. æqualis* is abundant; in the Chloritic it is hardly ever found. *Turrilites Morrisii* is, on the other hand, characteristic of this horizon.

The band of phosphatic nodules with crushed *Pecten asper* deserves attention. This species of *Pecten* is certainly not properly a Chloritic-Marl fossil; yet it only occurs in the peculiarly crushed state in this formation; it is never found in the Greensand proper in the Isle of Wight.

Discussion.

Mr. H. G. Fordham stated that between Ballard Hole and Punfield Cove the phosphatic nodules are scattered through the Chloritic Marl, and not confined to its base, and that no broken shells of *Pecten asper* occur at that point. He further remarked that the author gave the thickness of the Chloritic Marl as 6 feet, *i. e.* greater than previous authors.

The President stated that the new Ammonite mentioned by the author seemed to be intermediate between *A. rostratus* and *A. auritus*, but nearer to the former. *Pecten asper* had not previously been noticed above the Upper Greensand. He referred to the great value of Dr. Barrois's labours in connexion with the English Chalk.

Rev. J. F. Blake thought that the beds with *Ammonites inflatus* belonged to the Upper Gault, and not to the Greensand.

Mr. J. Starkie Gardner thought that, as species of *Pecten* and *Lima* have often a long range, their value for characterizing horizons in the Cretaceous was doubtful.

Mr. De Rance stated that *Pecten asper* in Dorsetshire never occurs above the Greensand. He agreed with Mr. Blake in regarding the zone of *Ammonites inflatus* as Upper Gault.

28. Notes *on a* Mammalian Jaw *from the* Purbeck Beds *at* Swanage, *Dorset.* By Edgar W. Willett, B.A. *With an Introduction by* Henry Willett, Esq., F.G.S. (Read May 25, 1881.)

(Communicated by the President.)

Introductory Remarks. By Henry Willett, Esq., F.G.S.

The rarity of the fossil remains of mammals in Mesozoic strata is a palæontological fact so well known to the Members of this Society, that it would be superfluous in me to do more than allude to it.

All needful information will be found in the exhaustive monograph (by one of the greatest living authorities on comparative anatomy, Prof. Owen) published in 1871 by the Palæontographical Society. From it I gather that in 1828 Mr. Broderip first discovered *Didelphys* in the Stonesfield-Slate quarry.

In 1858 the teeth of *Microlestes* were discovered by Mr. Moore in a breccia of Rhætic bone-bed and limestone filling a fissure in the Mountain Limestone at Frome, in Somersetshire.

In 1864 my friend Prof. Dawkins discovered a worn molar of a Marsupial mammal in the Rhætic beds at Watchet, in Somersetshire, called by him *Hypsiprimnopsis rhæticus* (*Microlestes rhæticus*). But it was to the personal energy and perseverance of Samuel Beckles, Esq., F.R.S., that science was indebted for the discovery of the great variety of these interesting fossils, the description of which occupies the largest portion of Prof. Owen's work (*loc. cit.*). My own imagination was excited by a popular account of Mr. Beckles's labours, written about 1858 by the late lamented Canon Kingsley; and the desire for further discovery caused me to pay several visits to the "Dirt-beds" at Swanage, in the hope of making further additions to the catalogue of Mammalian remains. Although I must have spent altogether many hours in search on several occasions, aided at times by local quarrymen, I could never succeed; but in 1878, having learnt that Mr. Beckles had been obliged, unwillingly and prematurely, to abandon his researches at a point which seemed rich in promise, I obtained leave from the Earl of Eldon, on certain reasonable conditions, to renew the inquiry at the point left by Mr. Beckles. The year 1879 was too wet and stormy to allow me to carry out my intention in so perilous a position.

There are *two* so-called "Dirt-beds" in the Purbecks of Durdleston Bay, Swanage. The lower one can be readily examined from the shore, as it rises at varying angles from beneath the sea-level until it is lost in the débris and turf above.

The upper dirt-bed, which also crops out at a similar angle, is less distinctly defined, until we reach a point about two thirds of the way up the cliff, just below the commodious refreshment-room erected on the summit of the cliff; and it was at this point (at which Mr. Beckles, hoping to resume his labours, had purposely cast down a large protecting accumulation of débris) that our attack was finally made in the summer of last year, 1880.

I must here render my tribute of thanks to my able coadjutor, Mr. Henry Keeping, of Cambridge, for the skill with which he directed the work, at no little peril to those engaged in it.

We commenced operations by scarping down the overhanging strata for a depth of 40 feet, laying bare an area about 13 feet by 10. This upper "dirt-bed" is of varying thickness, from 2 to 10 inches. It seems to have been a silt, filling up hollows and irregularities in the surface of the stratum immediately below it.

Aided by those earnest geologists Prof. Dawkins of Manchester, Mr. Charles Potter of Liverpool, Mr. Griffith of Cambridge, and several members of my own family, the area was most carefully broken up and examined. The research occupied ten days; and although we found several teeth and jaws (hereafter to be described), it was a fortuitous blow of the hammer of a local quarry-man that laid bare the interesting specimen about to be described.

The time of the meeting has already been trespassed upon too long by these preliminary remarks. I hope on some future occasion to supplement them by a further description of the fossils discovered, a more ample account of the probable conditions under which the deposits were formed, and the reasons which explain the rarity of discovery rather than the paucity in number of the Mammalian remains.

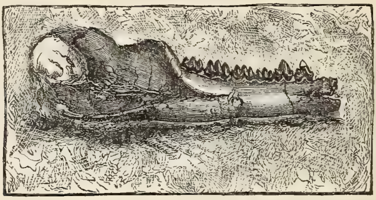
With the jaw of *Triconodon*, and in the same bed, were found Crocodilian remains (*Theriosuchus pusillus*, *Nannosuchus gracilidens*, and *Nuthetes destructor*), with other Mammalian and Reptilian fragments not easily determinable. There appears to be a single tooth of *Theriosuchus* amongst the fragments, but whether of *T. pusillus* is doubtful.

It will be remembered that rather more than twenty years ago extensive explorations were undertaken by Mr. Beckles, F.R.S., at Swanage, in search of Mammalian remains, and that he succeeded in unearthing some dozen new genera, including altogether sixteen new species of Mesozoic mammals. These fossils consisted principally of mandibles more or less broken, the only other bones found being portions of the upper jaw.

In the early summer of this year the permission of Lord Eldon was obtained to renew the search in Durdleston Bay, Swanage; and although this search was not followed by such brilliant results as in Mr. Beckles's case, it cannot be said to have been to no purpose, since a very good Mammalian jaw was obtained.

The specimen consists of the larger part of a right mandibular ramus, of which the condyle, the upper border of the coronoid process, and the symphysial end anterior to the second premolar are wanting. Six teeth altogether are preserved *in situ*, and, with the exception of the foremost, one are quite perfect. The genus to which the specimen belongs is *Triconodon,* Owen; but it differs

Fig. *Lower jaw of* Triconodon mordax, *Owen, from Swanage.*
Nat. size.



from those described by Prof. Owen in his Monograph on the Mesozoic Mammalia * in the fact that it has four teeth having the form of true molars, all those previously found (eleven or twelve in number) having each only three true molars, " a reduction rare in the Marsupial order," to which these mammals are usually ascribed. It may be noticed here that the nearly allied genus *Triacanthodon* has four true molars, but that the teeth now under consideration differ from those of this last-named genus in the following important details :—The fourth premolar of *Triacanthodon* approaches the triconodont or true molar type; and the apex of this tooth reaches only to half the height of the main cone of the preceding premolar, whereas the main cone of the fourth premolar of the new jaw is by far the largest of the three cones, and is rather longer than the corresponding cone of the preceding tooth; again, no hinder talon is found in any of the four molars of *Triacanthodon,* while it is well marked here on each tooth.

Of the six teeth preserved, four are, judging by form, true molars, and two are premolars, each of which is implanted by two roots; the two sockets for the next premolar are also plainly visible.

The crowns of both the premolars consist of a principal subcompressed cone, with a small and low anterior basal cusp, and a large and higher posterior one followed by a rudimentary talon; of the two the anterior tooth is rather the smaller.

All the true molars agree with the description of the type specimen of Prof. Owen in being " subcompressed, antero-posteriorly extended, and divided into three nearly equal cones in the same longitudinal line, the middle cone being very little larger than the front or hind cone; further, there is no cingulum on the outer side of the crown, but at the posterior margin of the posterior cone a rudimentary talon is feebly marked off by a short vertical indent from the rest of the surface of that cone." The first of the true

* 'Monograph of the Fossil Mammalia of the Mesozoic Formations,' by Prof. Owen, F.R.S. D.C.L. Printed for the Palæontographical Society. London 1871

molars is rather smaller than the others; and, as in the type specimen alluded to above (plate iii. figs. 7, 7 A, *loc. cit.*), the base of the coronoid process hides part of the last tooth. Prof. Owen considers that this character may indicate that the jaw described by him belonged to an individual not quite fully grown. Assuming such to be the case, the fourth molar in the present specimen would point to a mature animal, though, for a similar reason, to one not yet adult. In point of size, the last premolar and the three anterior molars agree as nearly as possible with the corresponding teeth in the type specimen of *Triconodon mordax.*

The question, therefore, to be settled is, Does the new specimen belong to this last-mentioned genus and species or not?

Prof. Flower, who has kindly examined it, and compared it with those found by Mr. Beckles, which are now in the British Museum, thinks, on the whole, that it may probably be referred to this species, and ingeniously suggests two hypotheses to account for the extra tooth of true molar form. They are as follows:—

As is well known, the deciduous teeth of the Marsupials, to which group the Mesozoic mammals have hitherto been assigned, consist of a single tooth on either side, the tooth which replaces this deciduous one being the last premolar. Assuming, then, that this tooth is still *in situ*, and is represented by the third tooth, counting from the symphysis, the dental formula will be p. m. 4 m. 3, which agrees with the type specimen of *Triconodon mordax* in the British Museum; and the first hypothesis is that the jaw belonged to a younger individual than any previously found, with the single milk-tooth in position.

The second hypothesis is to assume that all the teeth preserved belonged to the permanent set, when the dental formula will be p. m. 3, m. 4. In this case the four molars agree in number with those found in the adults of all recent Marsupials, and indicate a more fully matured specimen than any hitherto discovered.

A third hypothesis is to assume that it belongs to an altogether distinct species; but this, considering the close resemblance to *Triconodon mordax*, appears hardly necessary.

The lower border of the ramus is, in its present condition, nearly straight; but it has been much crushed, and when recent was, without doubt, slightly curved.

A small outlet of the dental canal opens under the foremost root of the third premolar (the first which is preserved); and there are traces of one, if not of two, other outlets anterior to this.

The total length of the jaw is 1½ inch.

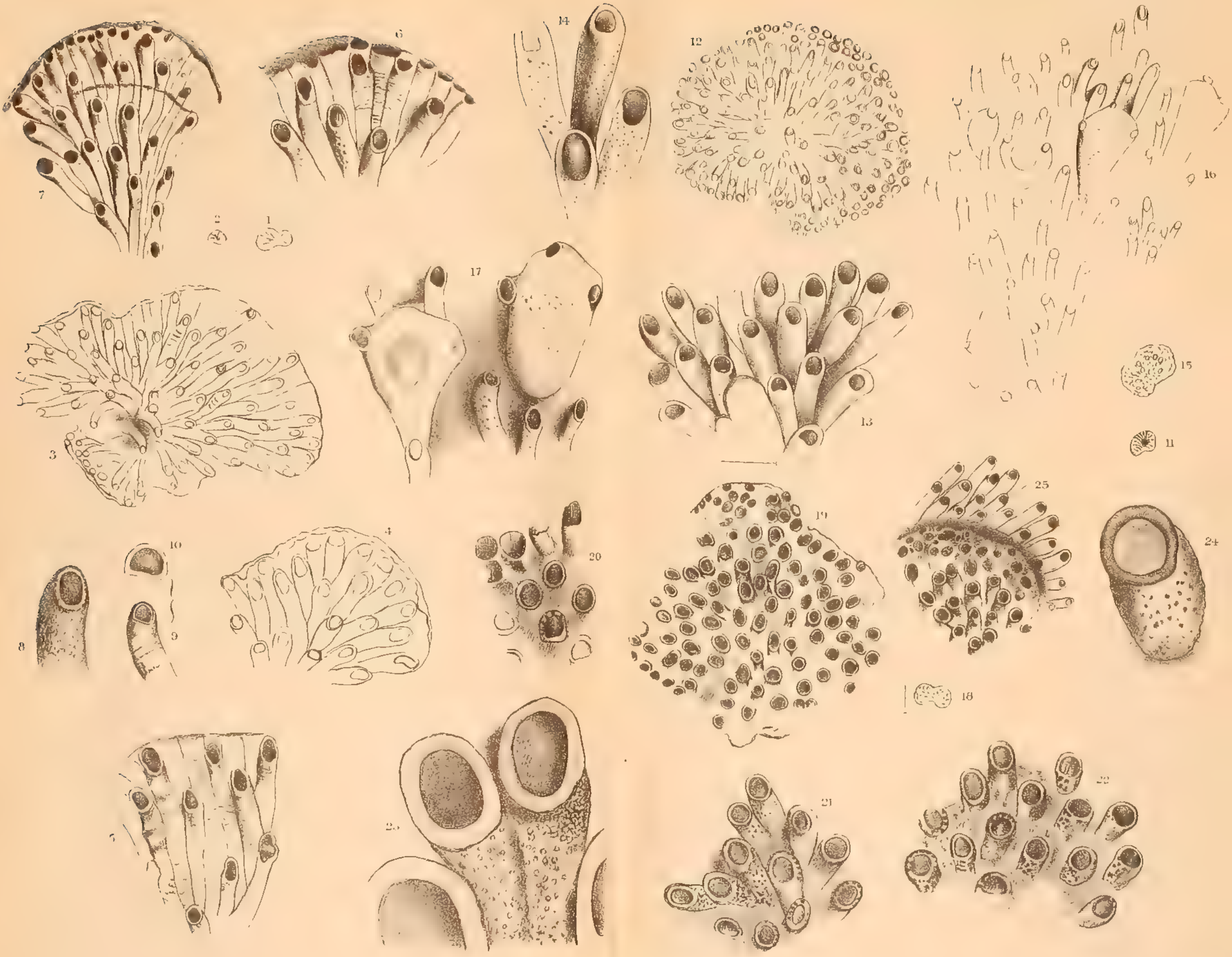
Discussion.

Mr. H. Willett said that he hoped the specimen would be accepted by the authorities of the School of Mines, and placed in the collection there.

Prof. Duncan spoke of the importance of the communication and the thoroughness which it showed. The jaw was a highly developed one; and had not the marsupial nature been suggested, it might have been considered to belong to the Insectivora; probably, however, it was an insectivorous marsupial. But was it so certain that the jaw belonged to a marsupial of the present type? It was strange also that these remains of marsupials had, at present, only been found in Europe. He was under the impression that the Australian marsupial fauna was not very ancient.

Mr. CHARLESWORTH said the history of the discovery of mammalian life in Britain was interesting. It had a important bearing on evolution. The explanation of the occurrence of lower jaws only was well known; but it was difficult to explain the disappearance of the phragmocones of Belemnites: also in East Anglia only teeth, antlers, and astragali of *Cervi* were found; other bones were wanting.

Mr. E. WILLETT said that mammalian remains had been recently found in great numbers in America, on about the same horizon, and that from them the discoverer, Prof. Marsh, was led to believe that all Mesozoic mammals belonged to a more generalized type than do the marsupials which at present exist.



A. S. Foord lith.

JURASSIC DIASTOPORIDÆ

29. *Further* Notes *on the Family* Diastoporidæ, *Busk. Species from the* Lias *and* Oolite. By George Robert Vine, Esq. (Communicated by Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S.) (Read January 19, 1881.)

[Plate XIX.]

Since my first paper, "A Review of the Family Diastoporidæ for the purpose of Classification"*, was written, a very important book has been published, namely 'A History of British Marine Polyzoa,' by the Rev. Thomas Hincks †. In this work the classification adopted by Prof. Busk in his Monograph of the Fossil Polyzoa of the Crag, 1859, and also in his British-Museum Catalogue, part iii. Cyclostomata, 1875, is set aside for one that I have little hesitation in saying will prove to be far more valuable to the working student. Instead of separating *Diastopora*, and making it the type of a family, Mr. Hincks places this genus with others in his second group of the Cyclostomata, which he calls Incrustata, D'Orb. The family name which he adopts is Fam. II. Tubuliporidæ, which includes the genera

Stomatopora, *Bronn.*	Entalophora, *Lamouroux.*
Tubulipora, *Lamarck.*	Diastopora, *Lamouroux* (pt.).
Idmonea, *Lamouroux.*	

Seeing that I have already committed myself to Prof. Busk's arrangement, it is impossible for me now to retreat; and, with this explanation, I must be excused for still adhering to the family name I used at first ‡.

In his remarks on the Cyclostomata, Mr. Hincks says:—"Simplicity is in the highest degree characteristic of the group; the cells are universally tubular; the polypide is without complexity of structure, and has a small number of tentacles; all appendicular organs are wanting" §. In another place he says:—"In classifying the Cyclostomata we have to base our divisions mainly on habit or mode of growth, on the plan according to which the zoœcia are aggregated together into colonies; the simplicity and general similarity of the cell throughout the tribe leave no other course open to us. We have to deal with very uniform structural elements very variously combined; and the modes of combination chiefly supply us with the bases of our system. Under

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 356 (August 1880).

† Van Voorst: 1880.

‡ Of the two evils I choose the least. To call my paper "Further Notes on the *Tubuliporidæ*" would be to commit myself to remarks on the other genera, which at present I have no intention of doing; and the retention of the family name Diastoporidæ, Busk, may have its special advantages.

§ Brit. Marine Polyzoa, Introduction, p. cxxv.

these circumstances we may not expect very strongly marked boundary lines" *.

The family Tubuliporidæ, Hincks, is thus defined:—"*Zoarium* entirely adherent, or more or less free and erect, multiform, often linear, or flabellate, or lobate, sometimes cylindrical; *Zoœcia* tubular, disposed in contiguous series, or in single lines; *Oœcium* an inflation of the surface of the zoarium at certain points, or a modified cell" †.

These further Notes have reference to the *Diastoporæ* found in the English Lias and Oolite, and are the results of a very careful study of material kindly and liberally placed at my disposal by two good local workers, Mr. E. A. Walford, of Banbury, and Mr. F. D. Longe, F.G.S., of Cheltenham. Whilst I was engaged in the study I was continually perplexed with the ever-varying modes of growth of what may be considered to be true *Diastoporæ*. To fix many of these forms under the descriptions already given by authors is indeed impossible; or to call them, arbitrarily, "species" or "varieties" would give a false idea of their significance. The wisest course to adopt is to call them "types;" and in giving them specific names I have kept this suggestion constantly before me. Between the Liassic and Oolitic forms very little variation is perceptible if we select groups of the same or similar habit. If, as in the Inferior Oolite, for instance, we take the three or four different types, and try to correlate them under one specific name, the varietal or typical divergency is at once apparent. In this paper I have directed the attention of the palæontologist more particularly to these typical forms; and it remains now for local workers to mark the differences well, and then, by a rigid and philosophical scrutiny, to try and ascertain whether any of these varietal types creep gradually from one into the other. The doing of this as it ought to be done depends on whether material for the scrutiny is accessible to the student; and besides the material, patience is needed to follow out a set design to its conclusion. To take away the stigma so continually repeated to our disadvantage, "the imperfection of the geological record," work done in the direction indicated must be attempted, even if it be imperfect; but, after going over only a small portion of the labours of two local workers, I believe it to be possible to carry out the design to perfection, or nearly so, if keen eyes and willing hands are engaged in the task.

I am not aware that previously to the labours of Prof. Quenstedt the attention of the palæontologist had ever been directed to Liassic Polyzoa. In his great work, 'Der Jura,' many Liassic fossils are described and figured, and amongst others we have figured and described the earliest known Mesozoic *Diastopora*. Quenstedt names it *D. liasica*; and he says of it, "One usually recogn the primary cell; at first a rapid increase occurs; but the polyzoarium soon divides itself into two groups, draws itself back, and

* Brit. Mar. Polyzoa, vol. i. p. 425.
† Ibid. vol. i. p. 424.

completes a perfect circle" *. He further says, *D. liasica* "occurs so abundantly, and precisely on shells of the Jurensis zone, that you can often identify your horizon from it." The specimen he figures is found on *Ammonites jurensis*.

Jules Haime †, in correlating *Berenicea striata*, says that this species was discovered by M. Terquem in the Lias of Valière. He says:—"*D. liasica*, Quenstedt, Handb. der Petrefact. p. 637, pl. lvi. fig. 10, "is closely related to this species: it begins in the same manner with a plate in the shape of a fan; but it branches out more on the outside."

Dumortier, in his 'Palæontological Studies of the Jurassic Deposits of the Basin of the Rhone,' recognizes another species, as he calls it, in the fourth part of the Superior Lias. This he names *D. crussolensis*; and the only distinguishing feature between this and *D. liasica* is "that it grows thicker than the last, and the form of the colony is more circular" ‡.

In Mr. E. A. Walford's pamphlet on some Upper and Middle Lias beds in the neighbourhood of Banbury §, the author relies upon Quenstedt's description for the identification of his specimens found in the zone of *Amm. spinatus*, and also in the transition-bed, on corals and shells.

In the best work on Oolitic Polyzoa that I have yet met with, 'Description of the Fossil Bryozoa of the Jurassic Formation' ||, Jules Haime divides his typical Diastoporidæ into two groups, the *Bereniceæ* and the *Diastoporæ*. The incrusting forms treated of as *Diastoporæ* in this paper belong to the first group of Haime. His species are:—*B. diluviana*, Lam., a common form of the Great Oolite; *B. Archiaci*, Haime; *B. microstoma*, Mich.; and *B. lucensis*, Haime. Both of these last are found in the Bradford Clay and the Great Oolite, very beautiful species with very characteristic cells. The *Diastoporæ* of Haime belong to the Foliaceous group. Another paper, by Prof. D. Brauns ¶, contains some very valuable information on both the foliaceous (especially *Elea*) and incrusting Diastoporidæ.

Mr. Walford has placed in my hands, for description or study, the whole of his local fossil Polyzoa; and so inadequately have the species been described and figured, that, for scientific purposes, the labours of these eminent palæontologists are almost useless. In giving the Liassic species a new name, I have had regard more particularly to its typical character than to any thing else. In this Liassic type I recognize a family likeness to later fossil and more recent *Stomatoporæ*; and it will be advantageous to science to draw attention to the fact.

* 'Der Jura,' pp. 279–292, fig. 1, tab. 40.
† Bryoz. fossiles de la form. Jurass., in Mém. Soc. Géol. de France, 1854.
‡ Dumortier, *l. c.* p. 226, pl. 48. figs. 11, 12.
§ Proceedings of the Warwickshire Naturalists' and Archæological Club, 1878.
|| *Loc. cit.*
¶ Zeitschr. d. deutschen geolog. Gesellsch. 1879.

1. Diastopora stomatoporides, mihi. Plate XIX. figs. 1–10.

? *D. liasica*, Quenstedt, Handb. der Petref. p. 637, pl. lvi. fig. 10.
? *D. crussolensis*, Dumortier, Palæont. Studies, p. 226, pl. xlviii. figs. 10 & 12.

Zoarium subcircular or orbicular, sometimes indefinite in its mode of growth, forming small isolated patches on shells or corals, varying in breadth from one and a half to three lines. *Zoœcia* arranged linearly, or nearly so, long and slender tubes, many of them wrinkled or surface-roughened, and adherent by their whole length; orifice, when perfect, oval, rarely circular. Primary zoœcia either very excentric in the larger colonies, or proximal in the smaller ones, which soon become excentric as the colonial growth increases. *Oœcia* rare, when present pyriform, involving at least two of the cells. Zoœcial tubes very faintly punctate.

Hab. On *Amm. cornucopiæ*, Up. Lias, Bloxham; on *Cardinia hybrida*, Sow., Appleton; and on *Montlivaltia Victoria*, Mid. Lias, zone of *Amm. Henleyi*, Cherrington, Oxfordshire; Sup. Lias, Crussol, Dumortier; on *Amm. jurensis*, in zone of ditto, Southern Germany, Quenstedt. "Deeper than this," says Quenstedt, "I have never found it."

A careful study of the figures given will convey to the palæontologist a very fair idea of the character of this very early Mesozoic type of *Diastopora*. Unlike any of the palæozoic types, it seems to be persistent, so far as the character of the cell is to be relied upon, high up into the Oolitic series, and, but for the peculiarity of its habit, might be recognized in the *Stomatopora diastoporides*, Norman, and the *Tubulipora lobulata*, Hassall *. Indeed, of the first of these species Mr. Hincks says "that it is the largest of British *Stomatoporæ*, and has very much the look of *Diastopora*;" and of the other species, "I can see no sufficient ground for placing *Tubulipora* and *Diastopora* in separate families; the two genera are nearly related, and have many common characters." He said this without being aware of the existence of the forms now figured and described, which are in every sense confirmatory of the justness of his family arrangement.

In the Oolitic series, beginning with the lowest beds—the Pea-Grit of the Inferior Oolite—we recognize altogether different types, not widely separated, but even on the same blocks. These types belong to the foliaceous as well as to the crustaceous forms; and where to draw the line between the two it is difficult to say. In some few cases the boundary lines are broken down; and one at least of the typical *Diastoporæ* pass from the crustaceous into the foliaceous form by a series of quiet gradations. Mr. Longe has given more attention to these forms than I have; and his remarks on these peculiar species may be referred to for exact information †. After

* Figures and description in Hincks's Brit. Polyzoa, vol. i. pp. 434 & 444, pls. 61 & 63.

† Geological Magazine, January 1881.

a careful study of the crustaceous forms from several horizons, ranging from the Pea-Grit to the Coral Rag, I can detect at least three types that have not been specially noticed, so far as I am aware, by previous authors. They may, and I have not the least doubt that they have been, casually identified; but that is all. They deserve, however, more than a passing notice, because some of these types, when they pass into the Bradford Clay and the Forest Marble, delicately preserved on branches of *Terebellaria* and fragments of broken shell, assume an altogether different character. Some of them are beautifully papyraceous; others appear to have a kind of basal lamina extending slightly beyond their circumference, a character I have never observed in the Inferior-Oolite species.

The papyraceous species of the Lower Oolite are also deserving of closer study than I can possibly give to them. Such work belongs rather to local students than to me. They, too, may study the types as they pass from one stratum to another; and in so doing, I would recommend them to mark the beginnings of the divergences, and the boundary lines of each of the four types given; and by doing so they will aid the palæontologist in classifying the evolutionary stages of a most important genus.

2. Diastopora ventricosa, mihi. Plate XIX. figs. 15–17.

Zoarium adnate, discoid in the earlier stages of growth, of most irregular outline in its later stages. *Zoœcia* produced and partially free in the centre, gradually depressed towards the margin; tubes slightly bent and swelling towards the orifice, which causes a constriction of the circular or subcircular mouth; cells well separated, the proximal ends being immersed in the zoarium. *Oœcia* very largely developed, sometimes round the margin, at other times indiscriminately all over the colony, involving two or three cells or only a considerable swelling of a single tube. In the best-preserved specimens the cells and also portions of the oœcia are finely punctate.

Hab. On a weathered and partially smoothed pebble (No. 5), Inferior Oolite, Pea-Grit, Cheltenham: Mr. Longe's Cabinet. On drift wood, Chipping Norton, lowest beds, Great Oolite: Mr. Walford's cabinet. Good specimens also in Museum of Practical Geology, Jermyn Street.

This species, or type, is a very peculiar one, well deserving especial study. I have it from several localities, ranging from the Pea-Grit to the Great Oolite. The specimen in Mr. Walford's cabinet contains innumerable colonies piled up very irregularly round a piece of water-logged coniferous wood of Oolitic age. The wood was originally large; but the broken fragment submitted to me for examination was about three inches long, and from half to three quarters of an inch in diameter. The incrustation of the wood, made up wholly of colonies of *Diastopora*, varies in thickness from a quarter to half an inch, the margins of the newer colonies gradually becoming compressed into the general mass through successive stages of growth. The *ventricose* swellings are not so typical in this specimen as in the more beautiful specimens from the Pea-Grit series (Mr. Longe's cabinet). One colony is five lines by four; and the oœcia are well developed, for there are no fewer than from 25 to 27 swellings in various stages of development; and it is from this specimen that the drawings (Plate XIX.) are taken. Measured across the cell-mouths, there are about six (or varying from five to seven) cells to a line. Three oœcia occupy about the same space. The earliest stages of colonial growth are disks with free cells, flabelliform at later stages, ultimately presenting the appearance of one continuous mass of immersed cells. On the broken edge of a fragment of Mr. Walford's specimen I can count from twenty to thirty layers, representing successive colonial growths.

It may be that some at least of the specimens of this type are the *Berenicea diluviana* of authors, and the *Diastopora verrucosa* of Milne-Edwards. *Berenicea Archiaci*, Haime, is closely related to this species; but the cells, and also the oœcia as figured by Haime*, are not so characteristic of our own Oolitic series as *D. ventricosa*.

3. Diastopora oolitica, mihi. Plate XIX. figs. 11–14.

Zoarium circular or nearly so, completely adnate, and varying in size from one to three lines in diameter either way. *Zoœcia* short and bulging near the distal, gradually contracting towards the proximal end; orifice variously shaped, the lower margin, in some cases, slightly mucronate (?); primary cell excentric. Central zoœcia partially raised, becoming gradually depressed towards the margin. *Oœcia*? Tubes faintly punctured, and no "adventitious tubules."

Range from the Pea-Grit to the Great Oolite.

Cabinets: (from several localities) my own; Miss Gatty's, Kidlington, Oxon; Mr. Longe's, very rich, from Pea-Grit; and also from Mr. Walford's; Museum of Practical Geology (several specimens on shells).

Hab. On stones and shells, forming small disk-like patches, more frequently isolated than clustering.

This delicate little species is the most abundant of the Oolitic *Diastoporæ*. From its peculiar habit specimens are generally referred by collectors to the *D. obelia* of Busk; and in my early identifications I was inclined to place it as a variety (var. *oolitica*) of that species. After drawing and carefully working out the type I soon found this to be impossible. The general habit is different; the cells are more closely packed, and their shapes are altogether different; and, above all, there is in none of the specimens I have examined any indication of "adventitious tubules." Judging from Manzoni's figure †, which he refers to *Berenicea striata*, J. Haime ‡, a doubt naturally suggested itself when correcting the proof of my first paper § as to whether some specimens of this type may be referred to Haime's species. There seems to be no identity either with that or

* Bryozoa Jurassic Form. pl. ix. fig. 11.

† Fig. 79, Bryozoa of the Pliocene of Castrocaro.

‡ Reuss, Die Bryoz. des braunen Jura von Balin, &c.

§ Quart. Journn. Geol. Soc. vol. xxxvi. p. 357, note.

Busk's *D. obelia*. *D. oolitica* is a very characteristic type, especially of the Pea-Grit Series, in the Cheltenham district at least.

Another type, not the least important of the whole group, is a most peculiar one. In general habit and mode of growth it seems to be a true *Diastopora*; but it must be looked upon more as a passage form than as a constant one in all its characters. The type of the cells, when slightly worn, approaches nearer to that of the Palæozoic *Ceramoporæ* than to any Mesozoic *Diastoporæ*; but in the more perfect cell the largely developed peristome is unlike any thing in the more ancient or the more recent Diastoporidæ. If this be a true passage-form, rather than a constant one, the tendency is toward the *Pustulopora-subverticellata* type*. In this type the cells are connate; but in the one under consideration only some few of the cells are connate; the great majority are "separated pores," as in ordinary *Diastoporæ*. My diagnosis is made from both the younger and older growths of several colonies; and the description may be relied upon, however the species may be placed in the future. In the Pea-Grit Series the cells have a very bold outline, with interspaces (in some places) between cell and cell. In one specimen from Chipping Norton the cells have a *Lepralia*-like growth, the colonies being semicircular and piled one upon another; and some of the cells are so immersed that only the peristome can be seen. In naming this "type" or "species," I desire to preserve a generic name, though the genus itself is now merged in that of *Entalophora* and *Spiropora*.

4. Diastopora cricopora, mihi. Plate XIX. figs. 18–25.

Zoarium adnate, forming small and large irregular patches, sometimes self-attached, at other times incrusting other species of Polyzoa. In the early stages of growth the colony has a bicircular or oval outline; in its later stages the growth is most irregular. *Zoœcia* short and stunted tubes, very coarsely punctate; orifice ring-like, with a largely developed peristome. Primary zoœcium inconspicuous, being deeply immersed, giving off to the right and left secondary zoœcia, which in their turn give off others. The after colonial growth is thus early directed to two opposite points; ultimately the proximal cells unite below the primary cell, so that it in time becomes centric or excentric. *Oœcia*?

Range from Pea-Grit to Great Oolite.

Cabinets: several very fine specimens of this type are in the cases of the Museum of Practical Geology, Jermyn Street; Mr. Longe's, Mr. Walford's, and Mr. Windus's.

Hab. Chiefly on water-worn stones and broken shells.

I have had very great difficulty in describing this type, more particularly on account of its peculiar preservation. One colony on Mr. Longe's specimens (block 6) is very well preserved in its earliest stages; and from this specimen most of the figures are drawn. The natural size is shown at fig. 18, and is about three lines at its widest

* See Busk's 'Crag Polyzoa,' pl. xviii. fig. 1, right-hand specimen.

part. In fig. 19 (an enlargement of a portion of the same colony) the tendency of the cells to the right and to the left is shown; the other figures are enlargements of special cells to show the ring-like character of the mouth and peristome. There is another colony on the back of the same slab; but this is very much worn, and the cell-mouths are somewhat angular. The largest colony is on block 9 *; and it is a very interesting study. This block is a piece of coarse Oolitic Limestone, much worn by attrition; and, besides many Serpulæ, it contains on its surface several colonies of Polyzoa. Fig. 25 is a magnified portion of a colony of *D. cricopora* adherent to a colony of *Elea* (?), or one of its nearest allies, the one almost wholly enveloping the other. In the fragment figured the different characters of the two fossils are shown. The under one of the *Elea* (?) type has all the cells in one plane, the walls of each cell so closely connected as to leave no interspaces. The normal orifice of the cell seems to be of a subcircular character; when slightly worn it is large and circular, unlike any of the cell-mouths figured by Busk in his 'Crag Polyzoa' as *Mesenteripora*, which seems to have been used as a synonym † of *Elea foliacea* (*D. foliacea*, Lamx.). Manzoni also figures ‡ a "*Diastopora*"? having a habit somewhat similar to this, which he calls *D. expansa*, Manz.; but the aperture is normally circular with a well-developed peristome. This flat adherent type of the Inferior Oolite becomes (so Mr. Longe informs me) foliaceous in its after stages; but whether it ever becomes really leaf-like with cells on both sides I cannot, as yet, satisfy myself. I have no desire, however, to put this type under the genus *Diastopora*. The other incrusting form is a marginal portion of *D. cricopora*, having many of the characters of the group, but with cells altogether at variance with the general build of the true *Diastopora*-cell.

The genus *Diastopora* has been, and is, in many instances, very much abused; and before proceeding with these studies it may be as well to define and limit the genus. Lamouroux used two terms which have come into general use—the one *Berenicea*, and the other *Diastopora*. Under these two names many divergent forms have been placed, so that to some extent *Berenicea* and *Diastopora* are synonymous terms, the term *Berenicea* being used for one section of the Diastoporidæ and *Diastopora* for another section. In subdividing the foliaceous Cyclostomata, Milne-Edwards formed two great groups, "distinguished," says Busk, "by the character that in the one the tubes are almost wholly immersed, and in the other partially free." To the former group Milne-Edwards applied the appellation "DIASTOPORES," and to the latter that of "TUBULIPORES." "This division is natural; but it seems convenient that it should be carried still further;

* These numbers refer to the specimens as numbered in Mr. Longe's cabinet. It would be a good thing to have the types preserved in some public museum, so that they could be accessible to future students. Whenever I could, I have referred to specimens so preserved.

† D'Orb., Pal. Franç. terr. Crét. (p. 808).

‡ Briozoi di Castrocaro, tav. vii. f. 83.

and in the doing of this . . . no better classification can be adopted than that suggested by the same author, viz. into 1. *Diastopores simples*; 2. *D. enveloppantes*; 3. *D. bisérialaires*. I propose, therefore, to term the simple *Diastoporæ* of Milne-Edwards *Diastopora*, the enveloping or laminated forms *Berenicea*, and the biserial *Mesenteripora*"*. This arrangement Mr. Busk follows in his 'Crag Polyzoa.' But *Mesenteripora* is placed as a genus of the Tubuliporidæ, whereas in the Museum Catalogue, part iii. Cyclostomata, it is placed as a genus of the Diastoporidæ. This I have no objection to, because it is only those who have gone over the same ground who can possibly know what difficulties there are to encounter in classifying the species under discussion. The differences, however, between Mr. Busk and Mr. Hincks† are very striking on this point. In the 'Catalogue of Cyclostomata,' *Mesenteripora* (a foliaceous form of the Diastoporidæ) is included in the FAMILY; whereas in 'British Marine Polyzoa' the foliaceous forms are included in the genus *Diastopora*. This I entirely object to, on account of the confusion it is sure to create when we are dealing with Mesozoic forms. With this exception *Diastopora*, in the sense in which I have used it, may be defined as follows:—

"*Zoarium* adnate and crustaceous, usually discoid or flabellate, less commonly irregular in form. *Zoœcia* tubular, with an elliptical or subcircular orifice, crowded, longitudinally arranged, in great part immersed."

The foliaceous species will have to be separately dealt with; and I think it very unwise to use the term *Berenicea*, as defined by Lamouroux, for other than Palæozoic species. If *Berenicea* is used for Palæozoic and Oolitic species indifferently, simply because the "corallum incrusts foreign bodies" and is "composed of a thin calcareous base"‡, confusion will be sure to follow, for the simple reason that the characters of the Palæozoic and Oolitic species are altogether different. The *Ceramoporæ* and *Bereniceæ* of the Palæozoic rocks are not typical *Diastoporæ*.

There now remain for investigation the Chalk- and Greensand-forms; and these I would gladly revise if Members would help me by the loan of material for this purpose. Some of the species catalogued are undoubtedly *Diastoporæ*; others are not *Diastoporæ* in the restricted sense used by me in this paper.

My thanks are due to kind friends who have assisted me with material for the writing of this paper—to Mr. Walford for supplying me with extracts and tracings from Dumortier and Prof. Braun, and to Mr. J. D. Longe, F.G.S., for the loan of specimens from the Inferior Oolite. I also tender my thanks to Mr. R. Etheridge, F.R.S., and to Mr. E. T. Newton, F.G.S., for allowing me to examine the specimens in the Museum of Practical Geology.

* Crag Polyzoa, p. 109.
† British Marine Polyzoa, p. 457.
‡ M'Coy, Brit. Pal. Foss. p. 44.

EXPLANATION OF PLATE XIX.

Figs. 1–10. *Diastopora stomatoporides*, Vine.

1, 2. Natural size of two different colonies.
3, 4, 7. Enlarged respectively about 10, and 15 diameters, to show the disposition and character of the cells.
5, 6. × 25 diam., showing the elongated character of cells, together with the rugose markings on some.
8. × 50 diam.
9. × 30 diam.
10. Aperture of cell, × 50 times, to show the true *Elea-foliacea* (*Diastopora*, Lamx.) type of peristome; from colony. Fig. 4. As above. (Compare *Berenicea striata*, Haime, pl. vii. fig. 8, *a*, *b*, 'Foss. Bryozoa of the Jurassic Formation.')

Figs. 11–14. *Diastopora oolitica*, Vine.

11. Natural size of colony.
12. × about 8 diam. There is much variation in this type; but it has generally a circular habit, as depicted.
13. × about 33 diam.
14. × about 50 diam.

Figs. 15–17. *Diastopora ventricosa*, Vine.

15. Natural size of colony. This also varies as to size of colony.
16. × 25 times, showing the disposition of the oœcial "gonœcia," Hincks, in the different parts of the colony.
17. × about 50 diam.

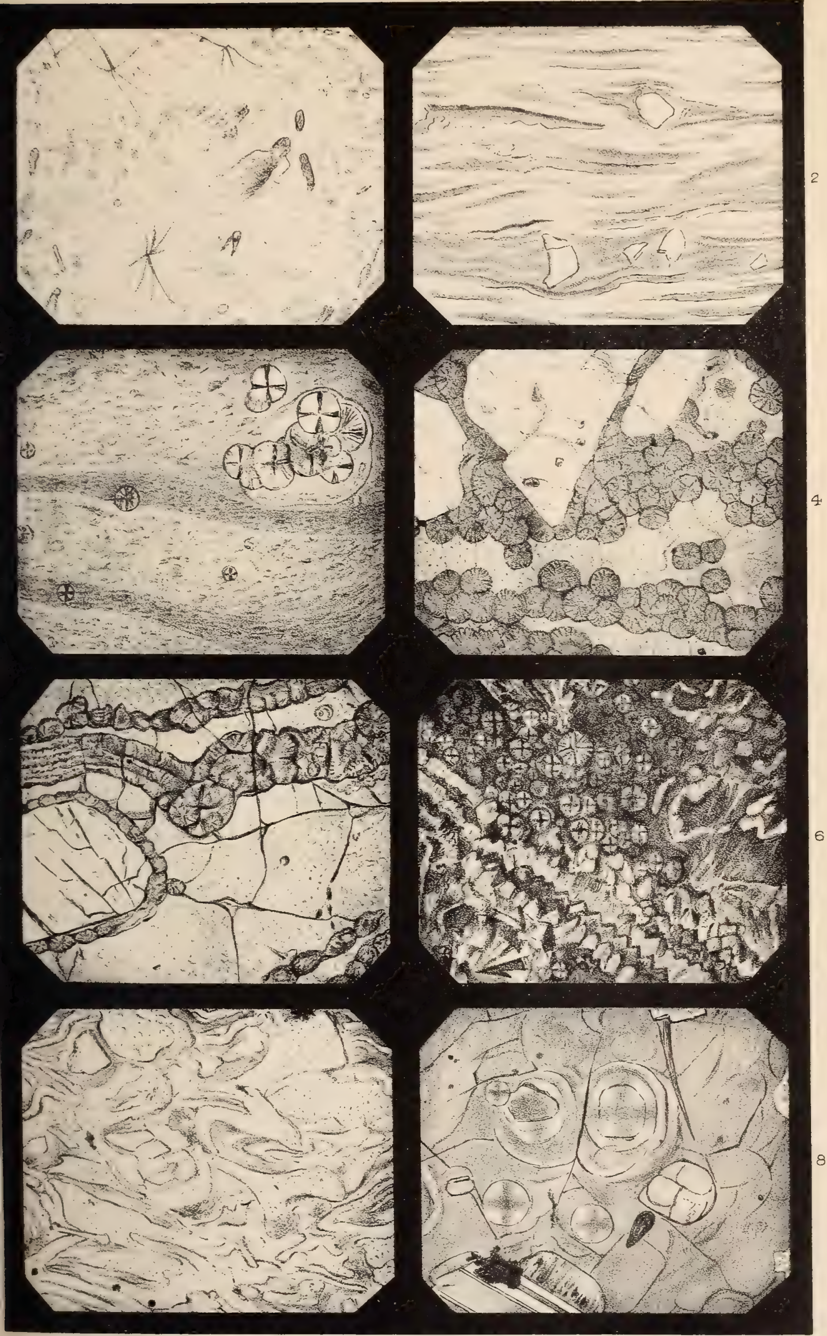
Figs. 18–25. *Diastopora cricopora*, Vine.

18. Natural size of colony from which the type is drawn. The specimens in the School of Mines vary considerably.
19. Portion of colony, enlarged in the direction of line I, fig. 18, to show the disposition of the partially immersed cells.
20–22. × 25 times, giving a fair illustration of the ornamentation of the cells.
23, 24. × 75 times.
25. Two separate colonies: the uppermost, *D. cricopora* (marginal edge), incrusting *Elea foliacea*, Lamx.

Discussion.

The President bore witness to the great value of the author's study of this group of microscopic organisms.

Prof. Seeley stated that his study of the Polyzoa had led him to conclude that many of the supposed generic differences were mere accidents of age and growth. He thought that Mr. Vine's paper was a valuable addition to science. He doubted the wisdom of inventing wholly new names for previously described species, as had been done in one instance by the author.



Frank Rutley del. A.S. Foord lith. Mintern Bros. imp.

VITREOUS ROCKS OF MONTANA. U.S.

30. *The* Microscopic Characters *of the* Vitreous Rocks *of* Montana, *U.S.A.* By Frank Rutley, Esq., F.G.S. *With an* Appendix by James Eccles, Esq., F.G.S. (Read April 6, 1881.)

[Plate XX.]

The specimens which have supplied the material for this paper were collected by Mr. James Eccles during a tour in Montana. They present so many interesting points of structure that a description of their microscopic characters may prove acceptable to those who are engaged in the study of British vitreous and devitrified rocks. Among the latter we have already found that certain structural peculiarities may still be clearly recognized, notwithstanding the changes which have led to their more or less complete devitrification. Through these changes, once vitreous rocks assume the character of felstones; and as it is highly probable that many of our ancient "felstones" and "hornstones" were once vitreous, it becomes important that we should note every structural peculiarity in glassy rocks of recent or late geological age which have undergone little or no change subsequent to their solidification. By doing this we are training our eyes to recognize similar structures in the devitrified obsidians, perlites, and pitchstones which ran over what are probably the earliest land-surfaces of which we have any trace. Zirkel, in his 'Microscopic Petrography of the 40th Parallel N.,' has described a large number of structures met with in the districts surveyed by Messrs. King, Hague, Emmons, and other members of the U.S. Government Survey; and it is to him we owe much of our knowledge concerning these minute structures. In this country the researches of Prof. Bonney and Mr. Allport have also served to increase the interest which rocks of this class will always possess. The more carefully and patiently we study the unaltered examples, the better shall we be able to deal with the questions which concern their older and no longer vitreous representatives; while researches upon artificial slags or glasses formed under known conditions, and modified by various known causes, either during or subsequent to solidification, will lend additional help in explaining minute structural peculiarities which still remain to be worked out.

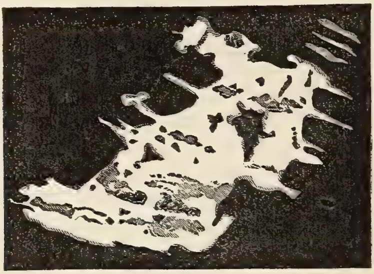
The following is a description of the microscopic characters of ten of the most interesting specimens (which may be regarded as fairly typical of the whole series) collected by Mr. Eccles in this district. In each case the letter *M* precedes the description of the microscopic characters.

No. 1. Yellowstone district. Black obsidian.

A black and perfectly vitreous rock, speckled with rather sparsely disseminated small greyish-white flecks, which are generally imperfectly developed felspar crystals.

M. In this section it is transparent and colourless, and is a remarkably homogeneous glass. The porphyritic crystals (which are not very numerous) are, in some if not in all cases, orthoclase. Some are perfectly developed; others present the most ragged and irregular boundaries, as in the accompanying figure (fig. 1). In

Fig. 1.—*Felspar Crystal in Obsidian (black), from the Yellowstone District.* (Magnified 55 times, crossed Nicols.)



this instance the spicular projections are sufficiently long and delicate to completely invalidate the supposition that the crystal is a broken fragment, and to render it absolutely certain that it has been developed during the cooling and solidification of the rock in which it occurs, or else that it is a partially dissolved crystal. This is an important piece of evidence, because less irregularly bounded imperfect crystals might often be erroneously regarded as included fragments taken up by and enveloped within the lava. Moreover it is interesting to see how, in such a remarkably homogeneous matrix, this crystal, if aborted, fails to assume the globular form, rounded at the angles, which is so common in the porphyritic crystals developed in most vitreous rocks. Under an amplification of 300 or 400 diameters numerous clear granules and opaque trichites are visible, as shown in fig. 1, Pl. XX.; and there are many small objects which may be elongated gas-pores; but, as they mostly pass diagonally through the section from the upper to the lower surface, it is not easy in all cases to ascertain their true character, owing to the impossibility of bringing them into focus throughout their entire length. Those which coincide with the planes of section certainly appear to be elongated, and sometimes tortuous, gas-pores. The trichites are sometimes straight, sometimes curved, and frequently form stellate groups.

No. 2. Yellowstone district. Obsidian.

Reddish-brown or Indian-red coloured rock, with some dark brown or black streaks and mottling, opaque, except in thin sections. Bright vitreous or slightly resinous lustre, and imperfect conchoidal fracture.

M. It is seen by transmitted light (fig. 2, Pl. XX.) to consist of delicate bands or strings of a clear yellow or orange-colour, with here and there a few bluish-black or grey strings. The material lying between these coloured strings, which are very closely packed, is a colourless or almost colourless glass. The yellow fibres depolarize in all azimuths except those coinciding with the directions of the principal sections of the crossed Nicols. There is therefore a marked optical difference between the yellow and the colourless bands, the latter being perfectly isotropic *. The generally parallel disposition of the bands imparts an appearance to the magnified section which very closely resembles the structure seen in a longitudinal section of wood; and this resemblance is further heightened by the deflection of the bands around small porphyritic crystals and fragments of quartz, which may be likened to little knots in wood. Although the greater portion of the preparation appears dark between crossed Nicols when the general direction of the bands is parallel with one or other of the Nicol-sections, still the deflected bands around the porphyritic crystals transmit a strong brownish-yellow light, because they do not, in this position, coincide with either of the Nicol-sections, so that around each brightly depolarizing porphyritic crystal there are also depolarizing fringes resembling smoothly-combed tresses of hair. Some of the porphyritic quartz-crystals have irregular creeks of glass passing into them, in some cases the yellow fibres being mixed with the included colourless glass, thus clearly showing that these quartz-crystals were actually developed within the rock prior to or during its solidification. The preparation also shows numerous dark opaque granules and a few dark sections, apparently of minute octohedra, which are opaque, except at their margins, where they feebly transmit light; and this imperfect opacity seems to imply that they are not magnetite. The fine banding in this rock is a most perfect example of fluxion-structure.

Representatives of this class of rock, similar in structure, but more or less devitrified, are to be found among the lavas of early Palæozoic age in North Wales.

No. 3. Yellowstone district. Black spherulitic obsidian.

A black glassy rock, containing numerous pinkish or pale-grey spherules irregularly distributed and varying from the size of a pea downwards to very small dimensions.

M. The section is seen to be traversed by bluish-grey and colourless bands, the former consisting of streams of microliths (fig. 3, Pl. XX.). In this banded structure there is no depolarization, showing that the banding in this case is quite different from that in the red obsidian just described. The spherules either occur isolated or in little colonies. Porphyritic felspar crystals occur here and there, and they show a few glass enclosures.

No. 4. Yellowstone district. Spherulitic-banded obsidian.

A rock consisting of dull dark grey and vitreous black bands, flecked with white porphyritic crystals of sanidine.

M. The dull bands are seen to consist of radiately crystalline spherules; while the deep-black bands visible in the hand-specimens appear in thin section as clear and colourless glass. In the drawing

* Since this paper was read, I have satisfied myself that the double refraction in these coloured bands is probably due to strain, a thick bundle of spun glass exhibiting similar phenomena.

(fig. 4, Pl. XX.) two portions of one and the same sanidine crystal, which between crossed Nicols undergo extinction synchronously in the same azimuth, are separated by spherulitic matter; and this seems to indicate that the spherules and crystals were probably developed at the same time.

No. 5. Yellowstone district. Black porphyritic obsidian.

A black glossy rock, with white porphyritic crystals, some of them $\frac{1}{8}$ inch long. A smoothly-ground surface shows fine, continuous, greyish, parallel bands and porphyritic crystals in a deep-black ground-mass. The fractured surfaces of the specimen are very irregular or small conchoidal.

M. The bands are seen to consist of closely aggregated spherules; and the surrounding glass is filled with streams of microliths, which impart a finely banded appearance to it. The porphyritic crystals lie with their longest axes in the same direction as the bands. One crystal (part of which is shown in fig. 5, Pl. XX.) is completely surrounded by a border of small spherules; and in another instance a little crystal lies immediately within a rudely concentric series of perlitic cracks. The section is fissured in all directions, the cracks traversing the glassy matrix, the spherulitic bands, and the porphyritic crystals; they must therefore have been produced subsequently to the formation of those bodies. A few of the porphyritic crystals in this rock bear a close resemblance to olivine. One transverse section of a rhombic prism gives an angle of 94°, which corresponds with the angle in olivine. The face of the section shows the granulated surface so frequently seen in olivine-sections; the angles of the crystal are slightly rounded; and the fringed cracks which traverse the crystal closely resemble those seen in olivine. The extinctions, moreover, in this crystal coincide with the directions of the crystallographic axes, assuming the section to be transverse to a rhombic prism. If this crystal be olivine (as I believe it to be), we have a curious instance, possibly the only one yet recorded, of olivine occurring in an obsidian. Zirkel, however, describes the occurrence of olivine in a trachyte from the top of Whitehead Peak in the Elkhead mountains, which he says "presents, beside sanidine, very many cracked quartzes as large as a pea, hornblende, and augite, and, what is remarkable, not very numerous but doubtless characteristic half-serpentinized olivines, the sections of which, measuring as high as 0·75 mm., are visible even to the naked eye in the slides. The peculiar quartz occurring here is therefore accompanied by a mineral which has never before been observed in a sanidine rock"*.

No. 6. Yellowstone district. Spherulite rock.

A pale bluish-grey rock, slightly cellular and with yellowish-brown stains, with numerous little porphyritic felspar crystals (chiefly sanidine) and, exceptionally, some roundish grains of quartz. On a smoothly-cut surface the rock is seen to consist almost wholly of closely aggregated spherules, with a little dark glassy interstitial matter. It is, in fact, an obsidian almost completely devitrified by

* "Microscopical Petrography," p. 159 (U.S. Exploration of the Fortieth Parallel: Washington, 1876).

the development of spherules and small porphyritic crystals, and may be regarded as a spherulitic condition of sanidine trachyte or rhyolite.

M. It is seen to consist of a multitude of spherules which possess a radiating, crystalline, or fibrous structure, and consequently show dark crosses between crossed Nicols (fig. 6, Pl. XX.). The spherules vary in diameter from about $\frac{1}{100}$ inch to extremely minute specks, when the section appears (in these parts) to pass into a microcrystalline condition, apparently identical with felsite. Indeed, from the microscopic study of this and many other more or less closely allied rocks, it appears to me desirable to abolish any hard lines of classification which have hitherto been drawn between the trachytes, rhyolites, and felstones. The spherules frequently form continuous and somewhat tortuous strings, which, between crossed Nicols, resemble the chenille put round the bottom of glass shades to exclude dust. The porphyritic felspars frequently fail to show any definite crystallographic boundaries, and are occasionally penetrated by creeks of the surrounding substance, which in one or two instances is included and shut off from the matrix. The porphyritic quartz-grains are often irregular in outline, and do not appear to have any good fluid enclosures.

No. 6*a*. Yellowstone Cañon. Quartz rhyolite.

A pale bluish-grey compact rock, showing delicate wavy fluxion-bands, which, on a smooth surface, are seen to thin off, seldom being continuous for more than an inch. Numerous small porphyritic grains of quartz and a very few crystals of sanidine are also visible.

M. The ground-mass of the rock is seen to be apparently micro-granular, while the bands also show a microcrystalline or crystalline-granular structure, but very much coarser. It is just the same textural difference which is still visible in microscopic sections of our archæan and palæozoic rhyolites. The ground-mass varies in texture in different parts of the section; and, where finest-grained, it is studded with little roundish blotches, which seem to depolarize more strongly, and which appear lighter than the ground-mass when the Nicols are crossed, and darker when they are set parallel, or when the section is seen by ordinary transmitted light. When examined with an amplification of about 250 diameters, these spots seem to be the result of devitrification; while by employing a quartz plate it is seen that the ground-mass is partially isotropic, and the doubly refracting spots appear to become more mixed with isotropic matter towards their margins. The spots, in fact, resemble segregations of doubly refracting granules, which impart a sort of spotty mottling to the ground-mass. The porphyritic quartz-crystals are nearly all rounded in outline, like those which occur in quartz-porphyries; but, unlike the latter, they seem to contain no fluid lacunæ. This rock affords interesting material for the study of devitrification.

No. 6*b*. Lower Geyser basin; is a pale grey or drab rock, with darker parallel bands. It is a banded spherulite rock, the bands consisting of small and the remainder of larger spherules. It closely resembles No. 6, except in the better definition of the bands. The rock contains some porphyritic felspar crystals.

No. 7. Quartz rhyolite. Gardiner's River.

Compact pale bluish-grey rock, containing numerous granules of quartz and a few crystals of sanidine. A rudely banded structure is visible on a smoothly cut surface of the specimen.

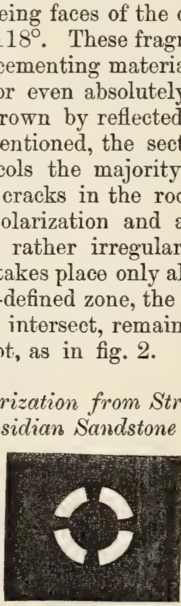
M. Shows curiously twisted and gnarled bands which end abruptly (fig. 7, Pl. XX.). This may, however, be in some instances due to their being cut off by the upper and lower surfaces of the preparation. The structure closely resembles the mottling on gun-barrels. In some of the thicker bands traces of a fibrous crystalline structure, transverse to the bands, is visible in polarized light; and this, taken in conjunction with the frequently looped or annular disposition of the bands, may be accepted as evidence that, at all events to some extent, the general structure of the rock is due to an attempt to develop spherules, but especially such as have an elongated axis, as in the axiolites described by Zirkel.

No. 8. Yellowstone district, Lower Geyser basin. Vitreous tuff ("obsidian sandstone").

A finely granular rock of a dark or blackish colour, with light specks. The granules have a vitreous lustre.

M. It is seen to be a tuff composed of small fragments of vitreous rocks which in most instances show well-marked perlitic structure (fig. 8, Pl. XX.), and detached crystals and fragments of crystals which in most cases appear to be sanidine and occasionally plagioclastic felspar. The transverse sections of some of the former are lozenge-shaped, the boundaries being faces of the oblique rhombic prism and giving an angle of about 118°. These fragments of rocks and crystals are bound together by a cementing material which, in a not very thin section, appears brown or even absolutely opaque by substage illumination, and reddish brown by reflected light. It is most likely limonite. As already mentioned, the section is a rather thick one; and between crossed Nicols the majority of the spheroidal spaces enclosed by the perlitic cracks in the rock-fragments exhibit more or less well-marked depolarization and a dark interference cross. The cross is sometimes rather irregular or distorted. In some instances depolarization takes place only along the bounding cracks; in others it forms a well-defined zone, the central portion, where the arms of the cross would intersect, remaining dark and forming an approximately round spot, as in fig. 2. These phenomena appear

Fig. 2.—*Areas of Depolarization from Strain within Perlitic Bodies in Obsidian Tuff ("Obsidian Sandstone"), Yellowstone District.*



most distinctly to be the result of strain; for Lommel* remarks,

* 'The Nature of Light,' p. 330 (International Scientific Series, London, 1875).

"the double refraction of compressed and suddenly cooled glass is nevertheless essentially different from that of crystals;" and he adds that, in order to project the system of rings of a strained glass disk upon a screen, using Dubosq's polarizing arrangement, it must be placed at a point where "the rays by which it is struck are nearly parallel, and traverse the plate in the same direction and with the same length of path. The difference of path which gives rise to the system of rings can therefore only be due to the fact that the *double refraction*, whilst the course of the rays remains unaltered, *increases towards the periphery of the plate.* In a crystal, on the contrary, the double refraction is at all points the same for the same direction of the rays." . . . .

Before proceeding another step I wish to place side by side with this statement an extract from the late Hermann Vogelsang's 'Krystalliten'*. Speaking of some crystallites in a piece of thick glass from the glass-works at Stolberg, he states that for a certain distance around these isotropic crystallites the glass exhibits double refraction, a neutral cross also traversing the anisotropic area. In one case he noticed a slight disturbance of this cross in the neighbourhood of an ellipsoidal body, which seemed to him to indicate that the strain in this instance was not constant in all directions; and he states, "It is also to be remarked that the glass at the boundary of the polarization-picture is sometimes traversed by a fissure, a spheroidally-running cleft. The polarizing action is not thereby disturbed. Whether these cracks were produced during the cooling of the glass, or whether they have subsequently been developed in the splitting-off and grinding of the preparation, I am unable to say." If the careful observer, who penned the lines I have just quoted, had seen the preparation which is now placed before you, I think that his doubts with regard to the origin of those spheroidal fissures would have vanished. We have here, I believe, additional confirmation of the views advocated by Professor Bonney, Mr. Allport, Mr. Cole, and myself with regard to the origin of perlitic structure. But we have something more. If Vogelsang's crystallites be embryonic crystals (as I think we may certainly assume that they are), we have a close relationship between crystallogenesis and perlitic fission; and, indeed, in the section to which our attention is now confined, there are plentiful examples of doubly refracting crystals which are immediately surrounded by perlitic cracks, but which do not, save very exceptionally, transgress those boundaries.

In a paper upon a somewhat kindred subject† I have already quoted a statement of Bischoff, to the effect that trachytic rocks, in passing from a vitreous to a crystalline state, undergo a shrinkage of nearly 10 per cent. of their original bulk. In those few instances in which a perlitic crack passes *through* a crystal, there is commonly another crystal developed by its side, which, with its surrounding

* 'Die Krystalliten,' Bonn, 1875, p. 68. Admirable figures of these crystallites are given in plates ix. and x. of the above work.

† "On some Structures in Obsidian, Perlite, and Leucite," Monthly Microscopical Journal, vol. xv. p. 183.

crack, may have been formed subsequently to the crystal which is traversed by that crack. What are we to infer from these crack-begirt crystals? Surely we have here something like the contraction experimentally determined by Bischof in rocks of precisely similar constitution. The crystal is a constituent of trachyte; it may be regarded even as a small piece of trachyte developed within obsidian. The strain upon the surrounding glass, engendered by the formation of this crystal, is, I have no doubt, the cause of the rupture in the surrounding glass; and the gape of the fissure is the measure of the contraction for any one plane. The polarization-figures seen within the perlitic areas surely, then, bespeak the incipient strain which heralds the production of the crystal; and I believe that the rounded boundaries and the curved cracks, so frequently seen within the angles of olivine and other crystals developed in vitreous rocks, are but another expression of the laws which crystallization enforces in a surrounding amorphous mass. In studying these questions we seem almost to stand upon the threshold of crystallography; and I may well close this paper with the hope that the subject may be taken up by more able hands; for it requires further investigation, since there are perlites in which no apparent relation exists between the perlitic structure and the porphyritic crystals—as in some of the perlites of Chemmitz, where even a score of small perlitoids may be seen to abut against the margin of a single crystal of sanidine or of magnesian mica. In these rocks we have, indeed, always assumed that the development of perlitic structure was subsequent to the formation of the porphyritic crystals, and not approximately synchronous with it, as I think has been the case in the materials of the obsidian tuff just described. In an inquiry of this kind thick sections, as well as thin ones, should be prepared and examined, and conclusion after conclusion discarded if needful, until the truth is reached. Indeed, I am not unwilling to believe that some of the phenomena which we have just discussed may be due to different operations of one force, or of different forces; and, just as the same mineral may sometimes be formed by a wet or by a dry process, so it is possible that similar structures may not always be due to the same cause.

Appendix.—*Microscopic Characters of Volcanic Rocks of Montana.*

No. 9 (the rock from Mount Washburn) is an andesite which seems to be intermediate in character between the augite- and the hornblende-andesites, and approximates in mineral constitution to a basalt.

The constituents are chiefly triclinic felspar, augite, hornblende, magnetite, and vitreous matter.

A little sanidine also appears to be present. The augite and hornblende crystals generally show a dark border when examined under the microscope with substage-illumination. By reflected light these borders appear of a bright rust-red, and are doubtless due to marginal decomposition of the hornblende and augite. These stains and granules of peroxide of iron impart a reddish brown-colour to the rock. The vitreous matter constitutes a considerable proportion of the ground-mass. A little bright green matter is also present, which appears to occupy irregular vesicles, and which is either green earth or some closely allied mineral of secondary origin. The angles of extinction of the felspars seem to indicate that the triclinic ones are labradorite.

The rock from Tower Falls closely resembles that just described, except that it contains apparently no augite and more hornblende. The crystals of the latter mineral are also surrounded by opaque borders, which are often broad, and consist of an internal zone of magnetite and an external one of hæmatite, which appears sharply defined at its contact with the magnetite. The rock is hornblende andesite. It is of paler colour than that from Mount Washburn, the hand-specimen being grey, with minute reddish brown, black, and white specks *.

APPENDIX.

On the Mode *of* Occurrence *of some of the* Volcanic Rocks *of Montana, U.S.A.* By James Eccles, Esq., F.G.S.

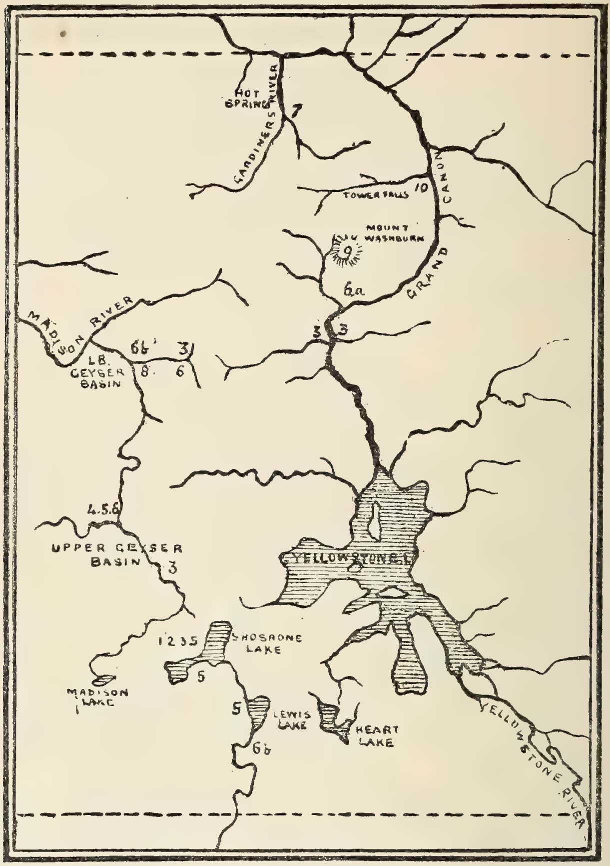
The volcanic district of the Yellowstone National Park, from which I obtained the various rock-specimens referred to in the foregoing paper, has been already described in detail by Dr. Hayden, Dr. A. C. Peale, and Prof. Bradley, in the reports of the U.S. Geological Survey of the Territories for the years 1871 and 1872.

In the autumn of 1878 I had the good fortune to accompany Dr. Hayden and other members of his survey in some parts of the district referred to; and although I have no intention of giving a detailed description of the volcanic phenomena which were observed, a short notice of the localities whence the specimens were obtained, and of the general mode of occurrence of the rocks, may be of some interest as a supplement to Mr. Rutley's description of their microscopic characters.

The Yellowstone National Park, within which are the head-waters of two of the great forks of the Missouri (the Yellowstone river and the Madison) and of the Snake river (one of the branches of the Columbia, comprises an area of about 3600 square miles, nearly the whole of which is covered up by volcanic rocks of great thickness. There are very few exposures of underlying sedimentary or other formations; and these are almost entirely limited to the extreme northern edge of the area. Some fifteen miles south of the southern boundary the extension of these volcanic rocks is seen to rest upon the northern spurs of the Teton range of mountains, at which point the underlying formation has been ascertained by Prof. Bradley to be of Carboniferous age. On approaching the Park from the south along the upper valley of the Snake, these volcanic rocks appear to form an irregular plateau densely covered with forest. From the point at which we first struck this plateau, as far as the Upper Geyser basin on the Firehole river (the chief branch of the Madison),

* For the discussion upon this paper see p. 412.

Fig. 3.—*Map of part of the Yellowstone Park.*
(Scale about 20 miles to 1 inch.)



is a linear distance of about twenty-five miles, but three days of hard travelling. The rocks consist entirely of varieties of obsidian and trachyte, the latter almost invariably being found in great mass under the former.

The obsidian, though frequent, is somewhat irregularly distributed. It is both black and reddish brown, is occasionally columnar, and is nearly always porphyritic. The most common form is a coarse, rapidly weathering variety, containing many crystals of sanidine. The disintegration of this rock produces some curious fine conglomeratic deposits in the old watercourses and river-beds (No. 8).

The trachyte is constant and of very great thickness, and is evidently closely allied to the obsidian. A cliff-section in the Upper Geyser basin suggests a transition from trachyte to obsidian. (Nos. 4 and 6 were obtained from this section.)

East of the Firehole river and across the divide between the Madison and Yellowstone rivers the section presents the same general characters as that between the Snake and the Madison. High up on the divide the trachytes are light in colour, and there is some pumice occurring on the surface. On the east of the divide the obsidian thins away for some distance, but is found again above the Great Cañon of the Yellowstone, where it is capped by fully 300 feet of fine sandstones and shales, probably of Quaternary age, which have doubtless been deposited by the Yellowstone lake in a former period of extension. The rocks in this basin, and especially in the section exposed in the Great Cañon, have been minutely described by Drs. Hayden and Peale; and I have nothing to add to their description. It is sufficient to say that the order and general character of the rocks is almost precisely the same as in the upper part of the Madison basin.

Up to this point the volcanic phenomena had been almost uniform. The trachyte-flows, although dipping slightly here and there (as much as 20° in the Upper Geyser basin), were approximately level; and the country through which I had passed seemed to be quite destitute of any features which I could recognize as vents from which such an enormous mass could have been poured out. Seven miles north of the head of the Cañon a change is observable. Mount Washburn here attains an elevation of from 2500 to 3000 feet above the trachytes of the Cañon, and is a true volcanic cone. The summit is a broken-down crater; and the lava-flows, which are basaltic (No. 9), dip away in all directions, and conform generally to the slopes of the mountain. I found no contact between the basalts and the trachytes on the southern side of the mountain; but it is quite evident that the former overlie, and are more recent than, the great mass of trachytic rocks just described.

Descending on the north side of the mountain, the Yellowstone river was reached again near Tower Falls, a distance of ten miles from the peak; and here the trachytes are again seen in the river-section, with columnar basalts resting on them. I was not sure whether these basalts had flowed from Mount Washburn or from some vent on the east side of the Yellowstone; but, compared with the trachytes, they were comparatively insignificant both in extent and, except on the mountain itself, in thickness. These basalts had been poured out before the formation of the present Cañon; for the river here cuts its way through basalt and trachyte nearly 400 feet deep.

The locality of Gardiner's river, whence the specimen No. 7 was obtained, as well as the intervening space between this river and Tower Falls, was passed over most rapidly by me, owing to bad weather and Indian troubles. The trachyte in this locality resembles strongly that of the Great Cañon in mineral character. Although there is a considerable distance between Tower Falls and Gardiner's river where the trachyte does not exist, owing, probably, to denudation, I am inclined to regard this Gardiner's-river trachyte as belonging to the great mass of trachytes further south.

EXPLANATION OF PLATE XX.

Vitreous rocks of Montana.

Fig. 1. Black obsidian containing trichites. Yellowstone district. × 250.

2. Red obsidian showing in thin section reddish-yellow bands of glass, and grains of quartz, in a nearly colourless glass. Yellowstone district. × 25.

3. Black spherulitic obsidian with bands of microliths and radiately crystalline spherules. Yellowstone district. × 77. Nicols at 85°.

4. Spherulitic obsidian, consisting of dull dark-greyish and vitreous black bands, flecked with white glassy porphyritic crystals of sanidine. The dull bands are composed of radiately crystalline spherules, while the vitreous bands consist of glass, black in the hand-specimen and colourless in thin section. Yellowstone district. × 25.

5. Black porphyritic obsidian with spherulitic bands. The drawing shows part of a section of one of the porphyritic crystals of sanidine, which is surrounded by an isolated girdle of small spherules. Yellowstone district. × 18.

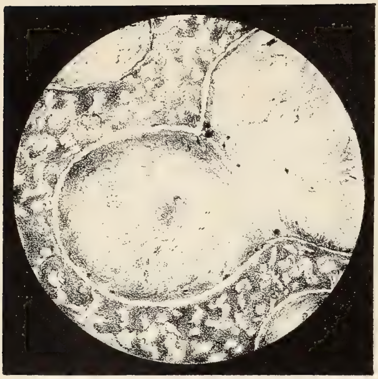
6. Yellowish grey spherulite rock with small porphyritic crystals of sanidine. Yellowstone. × 32. Crossed Nicols.

7. Rhyolite with peculiar Damascene structure and grains of quartz. Between crossed Nicols it is seen to have a microcrystalline structure throughout. Gardiner's River. × 55.

8. "Obsidian sandstone," a finely granular blackish tuff, composed of angular grains of vitreous rocks of different appearance, the majority being perlitic, others showing merely microlithic streaks, but all probably derived from approximately the same source and representing the disintegration and cementing in place of vitreous rocks. The drawing shows part of one of the perlitic fragments, in which, between crossed Nicols, an interference-cross is seen in the centres of some of the perlitic spheroids, similar to the crosses seen under similar circumstances in artificially strained or compressed glass. In the lower part of the field a crystal of triclinic felspar is shown. Lower Geyser basin, Yellowstone district. × 18. Nicols at 85°.

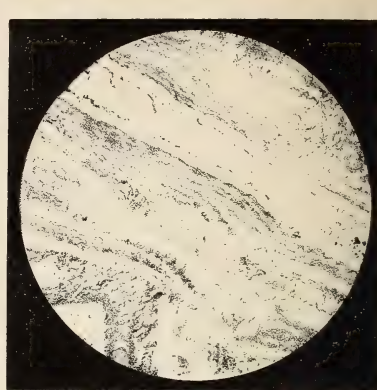
Note.—Except when otherwise stated, the drawings have been made by ordinary transmitted light.

1



x 18.

2



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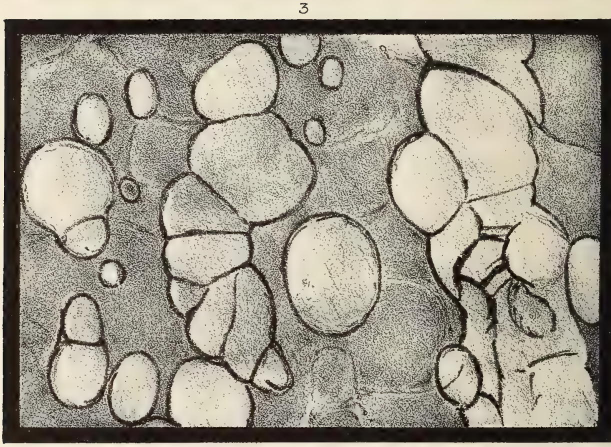

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x 25.

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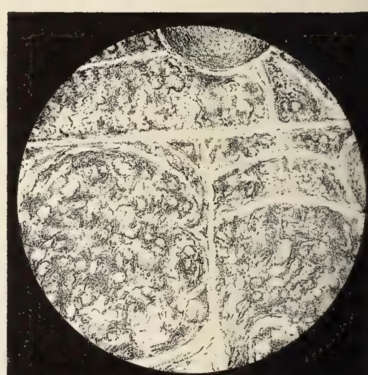


x 12.

Frank Rutley del. A. S. Foord lith.

Mintern Bros imp.

WELSH LAVAS OF LOWER SILURIAN AGE.

31. *On the* Microscopic Structure *of* Devitrified Rocks *from* Beddgelert *and* Snowdon ; *with an Appendix on the* Eruptive Rocks *of* Skomer Island. By Frank Rutley, Esq., F.G.S. (Read April 6, 1881.)

[Plate XXI.]

The specimen from the south side of the Capel Curig road, about $\frac{1}{4}$ mile from Beddgelert, which was collected by Mr. George G. Butler *, and which he kindly placed at my disposal, is a rather dark greenish-grey rock, spotted with pale greenish-grey spherules, some of which are over $\frac{1}{8}$ inch in diameter, and which, besides occurring isolated and in approximately spherical forms, have also coalesced, forming bands from $\frac{1}{8}$ inch to nearly $\frac{1}{4}$ inch in breadth. On a smoothly cut surface they afford, by their pale tint, a strong contrast to the dark matrix. The isolated spherules and spherulitic bands are shown in fig. 3 (Pl. XXI.) as they appear when magnified about 6 diameters. A thin section, when examined between crossed Nicols, is seen to be studded all over with small doubly refracting specks. By ordinary transmitted light, and under a power of 25 diameters, a marked difference is visible in the microscopic characters of the spherules and the matrix, the former being almost colourless, save for a few pale greenish flecks, which become more closely aggregated at the margins of the spherules, forming a somewhat darker border, while the matrix appears to consist of a closely matted or granulated deep-green substance resembling chlorite, through which are interspersed a great number of clear spots consisting of nearly colourless matter, similar to that which composes the spherules. Between the spherules and the matrix, forming a sharp boundary, is a clear, narrow, colourless border (fig. 1, Pl. XXI.), while the matrix itself is traversed by more or less sharply defined lines, which also appear clear and colourless.

These lines seem, in places, to be nearly straight, and to divide

* Extract from letter from G. G. Butler, Esq.:—

"With regard to the fragment of spherulitic felstone, I have only to say that I knocked it off the corner a piece of rock, perhaps 6 or 8 feet square and 2 or 3 high, projecting from a sloping field on the south side of the road from Beddgelert to Capel Curig—about a quarter of a mile from the former place, and perhaps 200 yards from the road, the field sloping down towards the road. The rock appeared to be *in situ*. I found similar specimens on other protruding rocks near, but none so perfect as this. I fear I cannot give any more information about it.

"A rock which abuts on the north side of the road, nearly opposite, but not so far from Beddgelert (in fact, just at the edge of the village), presents a curious appearance from a number of globular bodies contained in it averaging 2 or 3 inches in diameter and standing half out from its surface. When knocked in a careful way, they come out bodily, leaving an empty hemispherical socket.

"I remain, very truly yours,

"G. G. Butler."

the rock into small irregular cuboidal masses. They also describe irregular circles or ellipses, the sections of spheres and ellipsoids, which appear nearly to fill the spaces enclosed by the rectilinear divisions.

These straight and curved streaks have a very perceptible breadth (as shown in fig. 5, Pl. XXI., magnified about 12 diameters). Between crossed Nicols they break up into an infinity of small doubly-refracting granules; and we may infer that they represent small fissures which have subsequently been filled by infiltration.

The curved lines seem to indicate a coarse kind of perlitic or spheroidal structure; and their relation to the straight lines at once calls to mind the similar phenomena, on a larger scale, in the basalts of Le Puy and Rowley Regis, described by Professor Bonney*.

In one part of the matrix there is a roundish patch, somewhat less than $\frac{1}{10}$ inch in diameter, in which evident traces of perlitic structure are discernible. A portion of this patch, magnified 25 diameters, is shown in fig. 4, Pl. XXI.

The spherules and spherulitic bands are destitute of any definite internal arrangement. There is no trace either of radiating or of concentric structure. Under an amplification of 575 diameters the spherules are seen to consist of a confused aggregate of extremely minute, colourless, rounded granules and pale green scales: the latter appear to be chlorite. The little colourless granules closely resemble in appearance and in dimensions the granules of spessartine which occur in the Belgian honestones, and which have been determined and described by Renard†. Owing to their extremely small dimensions, they fail to occupy the entire thickness of the section; hence they are always overlain or underlain by doubly-refracting matter, which precludes the possibility of ascertaining whether they are isotropic. On examining a section of the coticule of Dressante, near Hebronval, in Belgium, given me by Prof. Renard, I find just the same difficulty, except upon the extreme margin of the section, where a few of the granules have parted from the preparation, and can be examined independently. In such cases the light, of course, undergoes extinction during a complete revolution between crossed Nicols.

Returning to the Beddgelert section, a few of the minute colourless granules may also be met with in an isolated condition; and their isotropic character can then be readily recognized. Under these circumstances we may, perhaps, be justified in regarding them as garnets, and possibly the manganese garnet spessartine‡. There is, indeed, a honestone, well known to the natives, and occurring in a quarry at Pen-y-Gwryd at the head of the Llanberis Pass, which, like its Belgian representative, contains numerous minute garnets

* "On Columnar, Fissile, and Spheroidal Structure," Quart. Journ. Geol. Soc. vol. xxxii. p. 140.

† Mémoire sur la structure et la composition minéralogique du Coticule: Brussels, 1877.

‡ Blowpipe examination of the finely powdered rock shows distinctly the presence of manganese.

identical in appearance with the little grains in the Beddgelert rock.

From the general character of this rock, from its spherules and spherulitic bands, and from the vestiges of perlitic structure which it presents, I have no hesitation in regarding it as a devitrified obsidian or pitchstone. This might, however, be inferred by any practised geologist without recourse to the microscope; and it is only right to add that Mr. Butler was well aware of its nature when he gave me the specimen.

The rock next to be described is associated with Bala beds, and occurs at Clogwyn d'ur Arddu, a high ridge about 1 mile N.W. of the summit of Snowdon. The specimen from which the section has been cut was collected long ago by Professor Ramsay*, and is now in the rock-collection in Jermyn Street.

The specimen is of a greenish grey colour, and shows an interesting weathered surface with projecting bands lying closely together, and separated by rather deep and narrow furrows. Speaking of these bands, Prof. Ramsay states that they "probably originated in the same cause that produced the lamination in the lava of Ascension"†. Under the microscope (fig. 2, Pl. XXI.) the section exhibits an irregular wavy-banded structure, such as might have been inferred from the banded character of the weathered surface. In polarized light this banding is marked by a strong difference in texture or grain; for the rock throughout is microcrystalline and is now felstone.

A comparison of this rock with unaltered banded obsidians of comparatively late geological age, such as those of Ascension, the Liparis, the Yellowstone, and other volcanic districts, leaves but little doubt that the structure has resulted from fluxion; and I think we may also assume that the rock was once vitreous.

On the right-hand side of the road, between Pont-y-Gromlech and Gorphwysfa, as we ascend the Llanberis Pass, an outcrop of dark grey felstone-like rock occurs, which breaks or splinters under the hammer into irregular slabs or platy fragments. The fissile structure appears at first sight to be due to the presence of dark greenish-black films with an oily lustre, resembling patches of talcose slate. It is, however, possible that other and more minute structure may also have some share in imparting this schistose character to the rock. In its present condition it may be termed a felsite schist; and it is probable that many geologists would, from the general appearance of hand-specimens, regard it as an indurated volcanic ash. For a long time the microscopic character of this rock has been a source of perplexity to me. Under the microscope, by ordinary transmitted light, the section is seen to be made up of small fragments, strings, and shreds of every shape, separated by finely granular and less translucent matter, which is strongly impregnated with a very pale greenish chloritic substance forming very

* By permission of Prof. Ramsay this description is now laid before the Society.

† Descriptive Catalogue of Rock-specimens in the Museum of Practical Geology, 3rd edit. (1862), p. 42, spec. 374, wall-case 41.

fine strings or films. Fig. 1 conveys a very fair idea of the general appearance of the section as seen by ordinary transmitted light, and magnified 55 diameters. Between crossed Nicols the shreds and

Fig. 1.—*Fissile Schist from near Pont-y-Gromlech.* (Magnified 55 diam.)

films are shown to be crystalline granular aggregates, which are in great part quartzose. Under a power giving about 250 diameters, the matter lying between the shreds appears to consist chiefly of very minute doubly-refracting granules; and I think that the whole rock simply presents different textural conditions of felstone, impregnated with some mineral of a chloritic or serpentinous character, possibly antigorite, since a porphyritic and schistose rock occurring just above Llyn Teyrn contains better-developed films of a similar character which closely resemble antigorite. The principal point of interest, however, is the meaning of the confused assemblage of many-shaped shreds which impart a distinctive character to thin sections of this rock. I think that a microscopic examination of the rhyolite from Gardiner's River, in Montana, U. S., described and figured in the paper on the rocks of that country which has already been laid before the Society, will suffice to show that it is approximately the same as the rock now under discussion.

I do not believe that the structural peculiarities by means of which the osteologist correlates the bones of one animal with those of another, are more trustworthy than the structural peculiarity visible in these two rocks. A thin section of a deep-red obsidian from Tolcsva in Hungary, given me by Professor Judd, is placed on the table for comparison with these rocks. When magnified (fig. 2), the pale glass which constitutes the ground-mass of the section is seen to be filled with minute strings of a reddish-brown glass, twisted in the most irregular manner. It will also be seen that the planes of

Fig. 2.—*Deep-red Obsidian from Tolcsva, near Tokay, Hungary.* (Magnified 250 diam.)

section cut off parts of these convoluted strings, leaving irregular-shaped shreds similar to those in the rocks from Gardiner's River and Pont-y-Gromlech, only very much smaller. The shreds in the latter rock appear, therefore, to be parts of convoluted strings or bands.

We are thus comparing the Pont-y-Gromlech rock with a distinctly vitreous rock (obsidian of Tolcsva), on the one hand, and with a rock which does not present a glassy aspect (rhyolite of Gardiner's River), on the other. A question of great interest now arises. Was the rhyolite of Gardiner's River once vitreous like the obsidian of Tolcsva? If so, then the Pont-y-Gromlech rock may be a devitrified obsidian. On the other hand we may be justified in assuming that the micro-crystalline condition of the rhyolite from Gardiner's River, and, indeed, that of any rhyolite, may be an *immediate* result of cooling, yet identical with the condition which often supervenes when solidified glassy rocks undergo devitrification.

We may therefore, I think, be allowed to consider the Pont-y-Gromlech rock either a rhyolite or a devitrified obsidian; for, in the first case, it may be regarded as an obsidian devitrified at its birth; in the second, as an obsidian devitrified in its old age. The peculiar structure of this rock cannot, however, be reconciled with any process of crystallization, but must rather be regarded as the result of fluxion in what, at the time, must have been a nearly or quite amorphous magma.

These considerations lead me to the conclusion that it is unwise either to employ too many names for rocks of the same character, or to give distinctly different names to rocks of different character which may once have been identical. Still there are difficulties in framing a new nomenclature; for, if we decline to speak of what we believe to be a devitrified obsidian as a rhyolite or a felstone, we commit ourselves to opinions concerning former lithological conditions, of which we sometimes have only very imperfect evidence. Moreover, if we decline to distinguish a rhyolite from an obsidian, we may with equal justice refuse to recognize a trachyte. It appears desirable to follow the classification of some of the continental petrologists in grouping all the highly-silicated vitreous rocks together under the term "hyaline rhyolite;" and, as our knowledge of this group increases, we may possibly find that its members differ more in structure than in any other respect, and that even many of the structures are common.

I have already stated that the Pont-y-Gromlech rock is now, to all intents and purposes, a felsite-schist * or felstone. Wherein lies the difference between a felstone and a rhyolite, so far as mineral constitution is concerned? The constituents are essentially felspar and quartz (similar to that in plutonic rocks), the felspar in felstones being chiefly orthoclase, and that in rhyolites the variety sanidine, which occurs only in volcanic rocks. In the majority of cases it is difficult to ascertain with certainty the precise nature of the minute crystalline granules of felspar in the ground-mass either of a felstone or of a rhyolite. The rhyolites commonly contain more or less vitreous matter; but in the older examples this, if it existed, has since undergone devitrification; and the product is a microcrystalline aggregate which cannot be distinguished from the rest of the rock, except perhaps in some instances by difference in texture. The difference therefore between a rhyolite and a felstone is mineralogically a very small one. The quartz-rhyolites or liparites are closely related to quartz-porphyry; so that here, again, we have a mineralogical affinity in rocks which are, on the one hand, volcanic, and, on the other, plutonic; and in many cases, especially among the older rocks, it is by structure alone that they can be distinguished. The quartz-porphyries may be regarded as spurs or dykes emanating from granitic masses; these dykes, like the margins of the granitic masses, are commonly poor in mica; or that mineral may be totally absent. The dykes, again, like the margins of the granitic masses, are usually fine-grained. We have, then, a tolerably well-defined series, consisting of:—

Rhyolitic series...	Hyaline rhyolites (obsidian, pitchstone, perlite, &c.), quartz-rhyolite, and trachyte.
Granitic series ...	Quartz-porphyry, and granite.

Trachyte bears much the same structural relation to quartz-rhyolite that granite does to quartz-porphyry. Bathymetrical conditions preclude the granitic series from having any vitreous representatives. That there is a passage from the granitic to the rhyolitic series, as suggested by many petrologists, seems more than probable. So far

* It is here worthy of remark that Daubrée has succeeded in superinducing schistose as well as fibrous and spherulitic structures in glass tubing, by heating it in presence of water up to a temperature of about 400° C., and under a pressure which he estimates at more than 1000 atmospheres (Études Synthétiques de Géologie Expérimentale, p. 156 *et seq.*).

as I can judge from microscopic examination of the eruptive rocks of the Llanberis Pass, the work which remains to be done is to fill in in detail, on a larger scale, the lines now laid down upon the 1-inch map.

I have already laid before this Society a description of a perlitic rock which occurs at the top of the Glyder Fawr; and I then expressed my belief that many more devitrified rocks would yet be found among the felstones of palæozoic age.

The present paper is probably a very small contribution to this list; and it is to be hoped that, as the list increases, we shall learn more precisely what a felstone is, and realize more fully what many of the felstones once were. The vitreous lavas were probably closely allied to trachytes. Other eruptive rocks, also occurring in the Snowdon area, such as those of Llyn-cwm-y-ffynon and Pont-y-Gromlech, are of a decidedly basic character. Thus we see that, as it is now, so it was in the vastly remote period which we call Silurian. The eruptive rocks of that age were both basic and acid; and their constituent minerals and structural features were similar to, if not identical with, those which exist in, but do not specially characterize the rocks erupted at the present day.

In view of these facts I think we may disclaim any power to determine the age of a rock by its mineral constitution or structure, and may protest, as Mr. Allport has done *, against the employment of different names for similar or once similar rocks, which differ only in point of age.

Appendix.

On the Eruptive Rocks of Skomer Island †.

Since the preceding paper was written I have examined some specimens from Skomer Island, off the coast of Pembrokeshire. For many years they have remained undescribed in the collection of rocks in the Museum of Practical Geology; and my suspicion of their true nature was first aroused by the close resemblance which one or two of them bore to other devitrified lavas which I had previously examined. Microscopic examination of these specimens shows conclusively that they are lavas of a once vitreous character. The sedimentary rocks with which they are associated are regarded as belonging to the Llandeilo or to the Bala series.

Only a short account of the microscopic characters of these lavas is here given, as they will be examined and described in greater detail in the forthcoming edition of the official catalogue of the rock-collection in Jermyn Street.

The specimens about to be described consist chiefly of banded and spherulitic rocks, now felstones, but once obsidians, the change being

* "On the Microscopic Structure and Composition of British Carboniferous Dolerites," Quart. Journ. Geol. Soc. vol. xxx. p. 565.

† The following particulars are now laid before the Society by permission of Prof. Ramsay, by whom also the specimens were collected.

due to the usual process of devitrification; while in some instances it is probable that the rocks have developed a spherulitic structure throughout, during solidification, in which cases they must be regarded as having been spherulite rocks from the first. Although none of these rocks retain a vitreous appearance, the minute structures which are developed in them are perfectly preserved, and are as clearly demonstrable as they would be in the most recent lavas.

The close resemblance in minute structure between these Skomer-Island lavas and those of the Yellowstone district in the United States is very striking, although their respective periods of eruption are so far removed from one another, namely—by all the time which elapsed between the deposition of the upper beds of the Lower Silurian series and certainly the lowest, if not the highest, beds of the Tertiary epoch. There is also a close resemblance between the Skomer-Island lavas and those of the Snowdon district. The period of eruption in both areas is nearly the same.

In vol. i. of the 'Memoirs of the Geological Survey of England and Wales' an account of the rocks of Marloes Bay and Musclewick Bay is given by Sir Henry De la Beche; but, although Skomer Island is situated close by, he makes no mention of it. At Wooltack Park, on the north of Marloes Bay, there are fossiliferous shales with some sandstones, beneath which it is stated that trap occurs resting on conglomerate and associated with shales. The whole of the igneous rocks of Skomer Island and the adjacent promontory have been mapped as greenstone.

It is, however, evident that Sir Henry De la Beche generalized to some extent in the mapping of these rocks, as the following extract from the 'Transactions of the Geological Society'* will prove:—

"All the north of Skomer Island consists of massive trap, having the character principally of fine-grained compact greenstone, and sometimes approaching to cornean. The small peninsula, however, to the east of the landing-place must be excepted, where some stratified rocks of ambiguous appearance occur. The southern part of the island consists of stratified greenstone dipping at about 48° to the south-east. Between this and the greenstone belonging to the north of the island a quartzose cornean, mostly striped, occurs. In some parts of the island hornblende is the prevailing ingredient of the rock."

In the same paper (at p. 2) Sir Henry states that he considers these traps to be "forcibly intruded amongst the other rocks at a period subsequent to their consolidation;" and he adds that, in applying the term "stratified" to trap, he only means to imply "that there is a parallelism of texture in the trap, which it has in common with a contiguous rock belonging to some other formation, and that this texture is also parallel to the common surface of separation between the trap and that other rock."

* Second series, vol. ii. p. 8.

Whether the banded obsidians, now felstones, are the "stratified rocks of ambiguous appearance" is a point which can only be decided by those who know the ground; or perhaps they may be the "striped quartzose cornean" alluded to as occurring between the northern and southern masses of greenstone which constitute the island. At all events, Sir Henry's description clearly shows that he had not overlooked these rocks, although he does not appear to have regarded them as lavas, or to have considered them of sufficient importance to indicate their position on the Survey map.

Rocks from Skomer Island.

1. Devitrified, banded obsidian.

A compact greenish-grey felstone, petrosilex or hornstone.

Under the microscope the banded structure is very clearly shown; and a minute spherulitic structure also occurs in places. The general condition of the rock is microcrystalline. A greenish substance is present in it, which appears to be chlorite. This rock is of much the same character as the devitrified obsidian or rhyolite from Clogwyn d'ur Arddu at the base of Snowdon.

2. Devitrified, banded and spherulitic obsidian.

A light greenish-grey to dark blackish-green rock.

The specimen shows a weathered surface, upon which numerous fine bands stand out in relief. The bands are much contorted.

Under the microscope the banding is well shown, and the spherules are well defined and very numerous. A perlitic structure is also clearly seen; and greenish matter in many cases pervades certain portions of the section. This green matter has in some cases a finely granular structure, or else contains fine dust, and exercises a weak depolarization when rotated between crossed Nicols. Spherules of much larger size than those which constitute the bands are likewise developed. They interrupt and appear to obliterate the fine spherulitic bands, which seem abruptly cut off by them. The crystallization in these larger spherules is much more confused than that in their smaller representatives; and consequently they show no dark cross between crossed Nicols.

The structures in this rock are as perfect as any to be met with in recent lavas.

3. Basalt or andesite.

An iron-grey rock with brown stains, compact in texture and showing some minute glistening felspar-crystals.

Under the microscope the rock is seen to be a finely crystalline admixture of triclinic felspar prisms, granules of augite, and crystals and grains of magnetite. Some isotropic matter seems also to occur in the matrix.

4. Quartz-oligoclase trachyte (?).

A greyish rock, with small white porphyritic crystals.

Under the microscope it is seen to consist of crystals of quartz and triclinic felspars (oligoclase) and orthoclastic felspar, with some magnetite in a fine microcrystalline matrix *.

The rock No. 4 is possibly the crystalline representative of the devitrified obsidians. The basalt (No. 3) is evidently an example of the greenstone which occurs so extensively at this spot. Some of the obsidians contain large spherical bodies sometimes an inch or more in diameter, which are best shown upon weathered surfaces. As these spherules are traversed by the fine bands which pass through the rocks in which they occur, it seems reasonable to assume that they have been developed subsequently to the solidification of the rock.

DESCRIPTION OF PLATE XXI.

Fig. 1. Devitrified spherulitic rock from Beddgelert, showing general character of spherules and matrix. ×18.

2. Devitrified obsidian or rhyolite from Clogwyn d'ur Arddu, Snowdon, showing banded fluxion-structure. ×18.

3. Devitrified spherulitic rock, No. 1. Beddgelert, showing spherules and spherulitic bands. ×6.

4. Ditto, showing portion of a perlitic patch. ×25.

5. Ditto, showing parts of spherules at top and right side of field, and infiltered shrinkage-cracks in matrix. ×12.

Discussion.

The Chairman spoke of the value of the papers and the interest of the agreement between rocks separated so widely in time or space. Some of those described by the author might be paralleled by instances from Arran and from the Auvergne.

Dr. Sorby said the most interesting part of the paper was the close relation of the structures described on the one hand to those of granite, and, on the other, to those of slags. The relation in structure between slags and the older rocks was of great interest.

Prof. Bonney expressed his sense of the value of the paper. In his opinion the only difference that could be maintained between rhyolite and felsite (he thought felstone should be used only as a group term) was structure; he would understand by rhyolite a trachytic rock in which a glassy base remained—by felsite those in which the matrix was crypto- or microcrystalline. He knew some of the rocks described by the author, and some remarkable spherulitic rocks, one showing a structure just like that of Pont-y-Gromlech on the east side of the Glyder.

Rev. J. F. Blake asked about the formation of the crystals with an inward growth, and whether large crystals did not indicate slow cooling.

Mr. Bauerman considered that the irregular strains in the obsidian fragment described by the author might be due to contraction

* The section cut from this specimen was hastily examined on the day upon which this paper was read; and I am not sure than it is not a clastic rock.

consequent on the passage of a glassy into a crystalline substance of sensibly the same composition; and instanced the inverse case of the fusion of felspar, where the increase of volume, in passing to a glass, fissures the crystal, in the direction of its principal cleavage, into laminæ, which are kept together by the glassy cement.

The Author said that the Arran rocks, so far as he knew, were intrusive; he quite agreed it would be well to use the term felstone in a wide sense. Mr. Blake's question had been answered by Mr. Bauerman, whose remarks on the fused felspar were of much importance.

32. Notes *on the* Fish-remains *of the* Bone-bed *at* Aust, *near* Bristol; *with the* Description *of some* new Genera *and* Species. By James W. Davis, Esq., F.G.S. &c., Hon. Secretary of the Yorkshire Geological Society. (Read May 11, 1881.)

[Plate XXII.]

I am indebted for the material on which the following paper is based to Mr. W. T. Ord, of Bristol, to the Council of the Geological Society at London, who have kindly placed their collection at my disposal, and to Mr. Sollas, Professor of Geology at the University College, Bristol.

The specimens are in good preservation, the smaller ones, consisting principally of teeth, being unbroken; the larger bones, as for example, ribs or other bones of Saurians, the larger spines of Fishes, &c., are generally found in a more or less fragmentary and broken condition.

From the occurrence of the teeth which are characteristic of the older Carboniferous rocks, such as *Psammodus porosus*, *Helodus*, and *Psephodus magnus* of the Mountain Limestone, and *Ctenoptychius,* which has hitherto been found in the Carboniferous series, and more especially in the Coal-measures, it appears probable that some of the fossil remains found in the Rhætic beds at Aust have been derived from the disintegration of the older rocks. Either this must have been the case, or the genera of fishes named had a considerably longer period of existence than has hitherto been supposed. It may be objected that the remains are in a very perfect state of preservation (as, indeed, they are in most cases) and do not appear to have been exposed to much attrition by being washed on the shore or bed of the sea or a lake. It is probable, however, that the area over which the bone-bed was deposited was composed, in the neighbourhood of Aust at any rate, of the blue clays which at present underlie it. During the formation of the bone-bed the nodular masses of blue-grey stone which are now found composing a great proportion of its mass were pieces of clay, rolled round by the action of the waves or tides, so soft that they received easily an impression of the bones or teeth which lay scattered along the shore with them. From the immense number of fossil remains of Saurians and Fish which occur in the bed, it will be inferred that it required a long period of time for their accumulation, and that throughout all that time there was a peculiar absence of sedimentary deposits, the nodular masses being derived from the adjoining Keuper beds, which also formed the floor on which the bone-bed was deposited.

In a paper read to this Society in 1841* Mr. Strickland showed the bone-bed to extend over a surface of 120 miles; and since that

* Proc. Geol. Soc. vol. iii. part ii. p. 585.

time Mr. Charles Moore, in an elaborate series of papers*, has proved with extreme minuteness and care that there extended over the Somersetshire and South Wales Coal-fields, and over the Mountain Limestone, beds containing Rhætic fossils, the crevices, veins, and pot-holes in the Mountain Limestone being filled up with organic reliquiæ of vertebrates as well as invertebrates of Rhætic age. These, according to Mr. Moore, have been washed in during the Rhætic and subsequent Liassic periods. Such being the case, the circumstances attending their deposition warrant the supposition that some of the fossils included in the Rhætic deposits were derived from the disintegration of the rocks on which they now rest. The bone-bed is variable in thickness, but rarely exceeds a few inches; at Aust it is from 3 in. or 4 in. to 9 in. thick; in many other places it is less, ranging over considerable areas with a thickness not exceeding one inch. There is also much diversity in the prevalence of organic remains. In a few localities the fish-remains occur in abundance, as at Aust, Axmouth, Coomb Hill, &c., whilst in other places they are entirely absent or are found very sparingly.

The fishes found in the bone-bed are comprised in the orders Plagiostomi and Ganoidei, the latter including, according to Prof. Miall †, the *Ceratodus*-remains. Besides *Ceratodus*, the Ganoids include the genera *Saurichthys*, *Gyrolepis*, *Lepidotus*, and *Amblypterus*.

Amongst the Plagiostomous genera may be enumerated *Hybodus*, *Acrodus*, *Sargodon* (?), *Nemacanthus*, *Sphenonchus*, *Lophodus*, *Squaloraia*.

There are also large numbers of bones, teeth, and other remains of Saurians, including *Ichthyosaurus*, *Nothosaurus*, *Scelidosaurus*, and others found and identified by Mr. Moore ‡.

A consideration of the characteristics of this mixed group of organic remains may afford some reasonable basis for deductions as to the circumstances under which they were accumulated. The Saurians would undoubtedly exist near and partly on land. The Ceratodonts, judging from a comparison of the forms of their teeth with the still existing *Ceratodus* of Australia, were vegetable feeders, and would require a shallow-water area from which to obtain their food. With respect to the remaining Ganoids, it is probable that they could freely exist in deeper water, and, from the character of their teeth, were probably predaceous in their habits. The Plagiostomous Sharks, with their sharp teeth and strong fin-spines, often attaining a large size, as evidenced by the great length of the latter, would be equally adapted for either deep or shallow waters. Taking all the items together, it would appear that the Rhætic beds were deposited in a shallow sea not far from the coast; that the Saurians passed a large proportion of their existence in the water, the remainder on

* Quart. Journ. Geol. Soc. vol. xvi. p. 483 (1860), vol. xxiii. p. 449 (1867), vol. xxxvii. p. 67 (1881).

† Palæontographical Soc., vol. xxxii. (1878).

‡ *Locc. citt.*

the land; of the fishes, the Sharks and some of the Ganoids frequented the shallow waters, probably in search of food. That they did so in large numbers, and spent considerable time there, is amply proved by the large number of coprolites.

Microscopical sections of the coprolites exhibit abundant evidence that the food of the Fishes or Saurians to which they owe their origin consisted of smaller fishes—fragments of bone, teeth, and other similar objects belonging to smaller or more slightly armed species of fish being found in larger proportions than any thing else with structure.

HYBODUS AUSTIENSIS, Davis. (Plate XXII. fig. 1.)

In the third volume of the 'Poissons Fossiles' M. Agassiz described a spine of *Hybodus*, of which there were several specimens in the cabinets of Lord Enniskillen and Sir P. Egerton, and in the museums at Oxford and Bristol; and an example is figured from the latter, which is about 6 inches in length. The spine is described as being round (that is, the sides are not so much compressed); and the ribs are more prominent, with deeper grooves between than in any other species described. The ribs do not anastomose, but run parallel to the anterior portion of the spine, and disappear along the posterior margin. There is a large cavity along the posterior surface; and the base of the spine is large proportionally to the remainder. The examples seen by M. Agassiz did not exhibit any traces of denticles sufficiently well preserved to enable him to describe them. Dr. Buckland and Sir Henry de la Beche knew the spine, and had previously considered it a variety of their *Ichthyodorulites dorsetiensis* (= *Hybodus reticulatus*, Agassiz) found at Lyme Regis. M. Agassiz further remarks that *H. minor* is not a small spine when compared with others he had described; but, at the same time, the spines found at Aust Cliff are not of large size, and are very different from the great spines found in the Lias at Lyme Regis. The teeth accompanying the spines are also different from those found at Lyme Regis; and altogether the differences are so great as to necessitate the institution of a new genus.

Since M. Agassiz wrote his great work, many fossil spines of *Hybodus* have been found in the Rhætic beds of Aust; and the collection at the Bristol Museum contains specimens which very nearly approach the sizes attained by the fine examples of *Hybodus reticulatus* and *formosus* of the Lias of Dorset. One of the largest examples would measure, when perfect, 13 inches in length, and fully an inch and a quarter in greatest diameter. The base presents the usual fibrous structure; it has been deeply and strongly implanted in the flesh. There is a large orifice or groove opening to the back of the spine at its base, and afterwards continued as an internal cavity towards the apex. The width of this orifice, from back to front, is about double that between the sides of the spine. The line dividing the base from the exposed portion extends with a convex curve from the anterior to the posterior portion of the spine, the convexity being towards the base. The anterior and lateral surfaces are ornamented with strongly marked ridges of enamel, which anastomose frequently, and present a somewhat wavy outline on account of the enamel forming the ridges not being of uniform thickness, in some places presenting a beaded appearance. The ribs lie roughly parallel with the anterior surface of the spine, and run out along the posterior edge, but not in a very well defined manner. The junction of the ribs with the basal portion is not so well defined as in *H. reticulatus*: in the latter the ends of the ribs rise above the surface of the base; whilst in the Aust specimen the ridges blend with the fibrous structure of the base, and the hollows between the ridges are below the level of the basal surface. The anterior and lateral portions of the spine have a circular or, rather, dome-shaped form in section. The posterior forms a wide base, not flat, but a little produced outwards towards the centre. The whole of the posterior portion higher than the open part of the cavity retains the fibrous structure of the base; and along each side of the median portion extends a row of blunt, laterally compressed, enamelled denticles; they are about ·2 inch across the base, and rise ·1 inch from the surface of the spine. Each denticle is separated from the next by a distance a little greater than its own diameter.

These spines differ from those of *H. reticulatus* in several particulars: their form is stronger and more robust; the lateral surfaces are rounder, and the base and cavity wider. In comparison with its width, the spine is shorter, not so gradually pointed, and less curved. The posterior denticles are not pointed and recurved towards the base, as they are in *H. reticulatus*; nor do its characters agree with those ascribed by M. Agassiz to *H. minor*, as already stated; and it appears necessary that a specific name to indicate this spine should be instituted: I suggest that it be *Hybodus austiensis*.

Hybodus punctatus, Davis. (Plate XXII. fig. 2.)

An imperfect spine from the bone-bed possesses characters which remove it from any other species hitherto described. It consists of the upper portion of a small spine 1 inch in length; the antero-posterior diameter is ·2 of an inch at its broadest part; the transverse diameter is a little less; the spine is slightly curved, more so on the anterior than the posterior surface, and tapers gradually to a point. The lateral surfaces are covered with longitudinal ridges, separated by grooves of about equal diameter, numbering five on each side. Along the bottom of each groove there are a number of minute pittings extending in a line parallel with the groove. Towards the points the ridges become less prominent and gradually disappear, the apex being quite smooth and without striæ. There is a row of denticles along each latero-posterior surface; they are prominent, obtusely pointed, laterally compressed. The internal prolongation of the pulp-cavity is comparatively small (less than one third the diameter of the spine), situated nearer the posterior than the anterior surface, and conforming in outline with the oval form of the spine.

Besides *Hybodus minor*, the only spine of this genus described by Prof. Agassiz from the Aust bed was *H. læviusculus**. The original which served for the description of the latter was a small fragment about half an inch in length, in the museum at Bristol. It is described as having smooth sides, slightly compressed, with an internal cavity rounder than the external form of the spine. There are denticles along the posterior border; and these are long, pointed, and recurved towards the base.

The spine I have from Aust, the only other small form of *Hybodus* which I have seen, differs in every respect, except size, from *H. læviusculus* of Agassiz. Its sides are deeply furrowed; the posterior denticles are short and blunt; and the internal cavity is much longer than broad in section.

The number of well-defined species of teeth of *Hybodus* found in the Rhætic beds of Aust would lead to the inference that there should be a similar variety in the fin-defences of the fishes. Under the most favourable circumstances it is an extremely difficult matter to correlate the dermal defences, either spines or scutes, of the Selachians with the teeth of the same genus; but in this instance the difficulties are greatly increased by the rolled and mixed state in which the specimens are found; and it appears improbable that remains will be discovered whose relationship will be rendered certain by the position or circumstances under which they are discovered. The pittings along the grooves suggest the name *punctatus* as appropriately designating this spine.

Remarks on the Genus NEMACANTHUS, *Ag.*

This genus was formed to embrace two species of fossil spines of Selachians found in the bone-bed at Aust. The spines are about 5 or 6 inches in length and ·7 inch in breadth in the larger species, viz. *N. monilifer*, and little more than half that size in the second one, *N. filifer*. The genus is characterized by the spine having its sides much compressed, and finely striated, with a small posterior cavity reaching half the length of the spine; where the cavity terminates on the posterior surface there commences on the sides a number of rounded tubercles: they originate near the anterior surface, extend obliquely across the spine, and run in parallel lines thence to its apex, a row extending along the junction of the lateral with the posterior face having some resemblance to a row of small blunt tubercles along each side. Along the anterior portion of the spine there extends a round keel, which is marked off from the body of the spine by a lateral canal along each side. In the larger species the lateral keel is of about the same diameter as the tubercles arranged along the sides. The smaller species, *N. filifer*, differs from the larger, *N. monilifer*, in the tenuity of its anterior keel, the smallness of the tubercles on its sides, and also of those extending along the posterior edges.

* Poissons Fossiles, tome iii. p. 46, tab. 10. figs. 24, 25, 26.

In the species described by M. Agassiz the spines are as nearly as possible twice as much in their antero-posterior as in in their transverse diameter. In a specimen from the Bristol Museum (Plate XXII. fig. 3) the spine from back to front has a diameter of ·35 inch; and its width across the posterior surface is ·3 inch, or very nearly equal to the antero-posterior diameter; the external posterior groove is shallow; and no denticles or tubercles are present. There is a very large median keel along the front of the spine. It is almost round, but rather wider than deep. It is composed of shining black enamel, and constitutes one fourth of the entire diameter of the spine. The spine is imperfect, the apical portion missing; so that it is impossible to say whether the sides were tuberculated. It appears to have been less curved than the common forms, the portion preserved being straight.

A second specimen, more closely resembling *N. filifer*, is a flat-sided spine of the ordinary kind (Plate XXII. fig. 4), finely striated along each lateral face. The anterior keel is small and threadlike; along the posterior surface are blunt, widely separated denticles. This spine is ·25 inch in diameter, and, when perfect, would probably be about 2 inches long. The sides of the spine are covered with longitudinal striæ as in the type specimens.

Both the varieties noticed above are from the collection of Mr. Ord, of Bristol, and were collected from the bone-bed at Aust Cliff.

Nemacanthus minor, Davis. (Plate XXII. fig. 5.)

Spine imperfect. Length 1·1 inch, diameter ·1 inch, when perfect probably nearly or about 2 inches in length. In section it is circular. A canal or internal cavity of similar form ascends the centre of the spine towards the point (the latter broken off in this specimen). There is no evidence that the cavity was open along the posterior surface; but it appears to have been terminal. The spine is slightly curved in form. Its surface is slightly and irregularly grooved, and is further ornamented by a number of minute papillæ. In the latter respect the spine resembles the genus *Nemacanthus*; but it differs in other essential respects from either of the two species described by Prof. Agassiz*. It does not exhibit any trace of having a ridge of any kind along the anterior surface; instead of that, it is round and indiscriminately spotted with papillæ or tubercles. The section of the spine is round, and not, as in the species of Agassiz, oval or triangular. It appears probable that the spine may belong to the genus *Nemacanthus*; but it is quite separated specifically. I propose the name *N. minor* in allusion to its small size compared with those previously described.

The specimen figured is in the museum of the Geological Society and is labelled "from the Fucoid bed, Wainlode Cliff," and was presented to the Society by H. E. Strickland, Esq.

* Poissons Fossiles, vol. iii. p. 26, tab. 7. figs. 9 & 10–15.

PALÆOSAURUS? STRICKLANDI, Davis. (Plate XXII. fig. 6.)

In the museum of the Geological Society, London, there is a tooth which I believe to be unique. It is from the Rhætic bone-bed of Combe-Hill, near Cheltenham, and was presented to the Society many years ago by Mr. H. E. Strickland.

The base of the tooth is wanting; the portion remaining is slightly more than ·6 of an inch in length. In section (fig. 6 *b*) the front portion is seen to be more compressed than the back. The lateral extremities of the tooth are slightly produced, and end in a serrated margin ascending to the crown or apex of the tooth, which is smooth. The width nearest the part of the base preserved is ·35 inch. The surface of the tooth, except along the lateral margin, is covered with fine longitudinal striations, which finally disappear before reaching the point.

This tooth has the appearance of having been washed and water-worn. The broken portion is smooth and polished; and it is probable that it may have been derived from an older rock, and redeposited amongst the remains of the Fishes and Saurians of the Rhætic age.

At a meeting of this Society held December 15th, 1841*, a paper was read by Mr. H. E. Strickland on the Bristol bone-bed, in which, along with other fossil remains, he mentions a "portion of a tooth with two finely serrated edges, and considered as probably belonging to a Saurian allied to the genus *Palæosaurus*;" there can be little doubt this is the same specimen. I have taken the liberty of associating the tooth with his name.

SPHENONCHUS (HYBODUS) OBTUSUS, Davis. (Plate XXII. fig. 7.)

The genus *Sphenonchus* was originated by M. Agassiz for the designation of certain objects which are regarded as teeth. It appears probable, as I shall attempt to show, that these objects were not teeth, but dermal defences. The specimen I am about to describe is ·45 inch in length and ·35 broad at the base: it is perfect, with the exception of a small fragment which is broken from the right portion of the base. The object, which appears homogeneous in structure, contracts rapidly from the base for a distance of about half its length. At this point its diameter is little more than a third that of the basal portion; and it remains the same to within a little of the point, which is slightly wider and thinner than the stem. The general form is that characteristic of the genus. It is arched forward, and does not possess any secondary denticles. The upper portion is nearly cylindrical, with the point flattened out like a chisel; near the base the form is three-sided; right and left it is produced so as to form wing-like processes; whilst down the centre of the anterior curved portion a third process is developed, which is continued and increases in size to the lowest portion of the base. The posterior surface, in its basal portion, is slightly hollowed inwards (fig. 7 *b*), compensating a little for the ridge in front. The whole of the surface is smooth and covered with shining enamel.

* Proc. Geol. Soc. vol. iii. pt. ii. p. 585.

Agassiz, in the third volume of the 'Poissons Fossiles,' describes three species of this genus:—*S. hamatus*, from the Lias of Lyme Regis, in the collection of the Earl of Enniskillen; *S. elongatus*, found by Dr. Mantell in Tilgate Forest; and *S. Martini*, Rob., from the Portland Oolites of Linksfield. These species vary greatly in form and general appearance; but in each the generic characters are well developed. The cylindrical cone forming the upper tooth-like portion is bent over anteriorly, the basal portion spread out in aliform processes; and a third median ridge or process is developed from the anterior surface of the base. The specimen I have described from Aust shares these peculiarities; but in detail it appears sufficiently distinct to form a new species. It is also from a horizon earlier and lower than any of those mentioned above; and though it may probably be found necessary to modify the specific relationship of these objects when more is known of them, at present evidence is wanting to indicate that they are not distinct species.

Sphenonchus hamatus, Agass., is remarkable for its extremely arched form and the pointed termination of the tooth-like part: it is an inch in length; and its base is widely expanded. *S. Martini*, Rob., is somewhat similar to *S. hamatus*, but is shorter and less curved. The third species, *S. elongatus*, is much larger than either of the others; the cylindrical portion is expanded at first, contracting nearer the extremity, and ending in a second expansion, "en sorte que sa forme ressemble un peu à celle d'une bouteille qu'on aurait recourbée." *Sphenonchus obtusus* differs from *S. hamatus* in its smaller size, less expanded base, and in its curvature being at a considerably smaller angle: its apical termination, wide, flattened and obtusely rounded, is in marked contrast to the finely pointed end of *S. hamatus*. *S. obtusus* has altogether a finer and less stumpy form than that of *S. Martini*, whilst from *S. elongatus* it is easily distinguished by its smaller size and the nearly uniform diameter of the upper portion.

I suggest the specific name *obtusus* to designate this species, in reference to its wide and expanded apex. The specimens are from the cabinet of Mr. Ord.

Prof. Agassiz described the genus *Sphenonchus* as a member of the family of Hybodontes, associated with *Hybodus, Cladodus*, and *Diplodus*. Since the classical work of Agassiz was completed, *Diplodus* has been proved to be the tooth of *Pleuracanthus*, and must consequently be removed from the family of Hybodontes, and considered in connexion with the spine as nearly associated with the recent Rays, according to Agassiz; or, as I have attempted to show in a former communication, it may have some affinities with the group of the Siluroids. *Sphenonchus* and *Diplodus* are referred to in the 'Poissons Fossiles' as offering considerable difference in microscopical structure from *Hybodus* and *Cladodus*, especially the former, which, whilst having a dense coating of dentine, has a large internal pulp-cavity, which is very different from the tooth-structure of either of the others. In the Magazine of Natural History* Mr. Charlesworth has described the fossil remains of a species of *Hybodus*, collected by Miss Anning at Lyme Regis. In connexion with the spine and teeth there is a bone which is undoubtedly an example of *Sphenonchus*, and is regarded by Prof. Agassiz in that light; in the same volume (p. 605) there is a letter from Miss Anning, saying that the hooked tooth (*Sphenonchus*) is by no means new, but that it has been frequently found at Lyme Regis in connexion with the teeth and spines of *Hybodus* or the teeth of *Acrodus*.

Mr. Charlesworth suggested that the hooked tooth is a dermal appendage or defence, probably situated immediately behind the head. Specimens since discovered prove that this suggestion was correct, and that two or three of these bodies were located on the occipital region of the head of *Hybodus*. The microscopical structure of the teeth and dermal defences of the Elasmobranch fishes is very similar, one of the principal differences being the large size of the pulp-cavity of the dermal processes as compared with that of the teeth; and in this respect Prof. Agassiz has shown that there is a great difference between the teeth of *Hybodus* or *Cladodus* and *Sphenonchus*. The base of *Sphenonchus* is excessively expanded, especially in *S. hamatus* from the Lias; and its fibrous structure without enamel indicates that it was imbedded in the flesh; it appears in this respect to resemble the dermal defences of *Raia clavata* from the Tertiary deposits.

In addition to the specimens already named, there are a number of the bones of the head, including jaws with teeth, of *Saurichthys*?; these I have handed to Mr. Sollas, who has already in preparation a paper on the same genus, derived from the examination of similar specimens in his possession.

Large numbers of fragmentary bones and small teeth are found scattered throughout the mass of the bed, but without sufficiently well established characters to enable an account to be given of them. A large operculum, nearly $2\frac{1}{2}$ inches in diameter, probably belonging to *Ceratodus*, and several bones with articular extremities, which may belong to the same genus, are included in the collection of Mr. Ord.

Besides the palatal teeth of *Psammodus* and *Cochliodus*, in all probability derived from the Mountain Limestone which underlies the Rhætic beds in some parts of the area, the following species of *Ctenoptychius* have probably been derived from the Coal-measures, and the *Petalodus* from within the Coal-measures or the Limestone. Specimens of *Helodus* have also been met with; they appear to belong or are very nearly related to *H. simplex*.

Ctenoptychius Ordii, Davis. (Plate XXII. fig. 8.)

Tooth. Length ·55 inch. Depth ·3 inch. A portion of the base is wanting.

The superior surface is folded so as to form a pectinated edge

* Vol. iii. p. 242, 1839.

extending along the crown, which occupies the greatest diameter of the tooth. It is slightly circular towards each end, the central part being almost straight. It is very thin, and appears to have constituted a sharp cutting-edge. The foldings are produced at their extremities into small and separated denticles, about 24 in number, whose diameter is greater from back to front than laterally. Some of these are broken at the tips; and the section thus exposed, when magnified, shows that a hollow tube ascended in the centre of each. The sulci descending to the body of the tooth from the denticulations are much more marked towards the lateral extremities than in the median region. Towards the base the tooth becomes gradually thicker; at the same time it also converges laterally to two thirds the diameter of the crown; from this part the tooth is broken off; but, from the impression on the matrix, it appears to have terminated in a broadly expanded rounded base. The tooth is attached to the matrix; and consequently the posterior surface is not exposed. The whole of the upper part of the anterior surface, above the root or base, is covered with a smooth polished surface of ganoine. From the base of the plications or foldings forming the crown of the tooth the surface extends towards the base in the form of a semicircular hollow.

This genus of Selachians was instituted by Agassiz (Poiss. Foss. tom. iii. p. 99) for the accommodation of teeth obtained from the Coal-measures of Staffordshire and Lancashire. Since that time specimens have been found in the Limestone of Armagh, and also in the Coal-measures and Limestones of Virginia, Illinois, and other localities in America. Hitherto specimens of the genus have been restricted to the Carboniferous group of rocks.

The specimen now described may either have been derived from the disintegration of coal-measure strata, and washed into the Rhætic beds during their deposition; or it may have belonged to a fish which lived during the period when those deposits were accumulating. It is probable that the former is the correct supposition.

The species from Aust differs materially from the type species of Agassiz, *C. apicalis*. The latter is possessed of only seven or eight protuberances from the crown of the tooth, the centre one being considerably larger and forming an apex to those on either side. *C. semicircularis*, N. & W., from the Coal-measure limestone of Ohio, bears a remarkably close resemblance to *C. apicalis* of Agassiz, and seems to be so little removed as scarcely to necessitate a separate specific name. *Ctenoptychius Ordii* bears some resemblance to *C. denticulatus*, Agass. (*loc. cit.* p. 101), in possessing a large number of serrations closely ranged along the crown of the tooth, whose lower portions form a series of plications extending to the body of the tooth and there disappearing; but in *C. denticulatus* the curvatures extend quite straight across the crown, whilst in the Aust specimen they form a semicircle. The base of the tooth in *C. denticulatus* is also much wider than in *C. Ordii*.

Ctenoptychius serratus, Ord (Sedgw. and M'Coy, Brit. Pal. Fossils &c. p. 626, pl. 3. i. figs. 21, 22, 23), from the limestone of Armagh, bears a greater resemblance to this specimen than, perhaps, any others; but it may be easily distinguished by the greater breadth of the crown of the tooth compared with its depth, the comparatively wide and short, somewhat cone-shaped character of the denticles, and the tips of such denticles appearing minutely crenulated under the lens.

The specimens serving for the above descriptions were collected at Aust by Mr. Ord, and are from his cabinet. In recognition of his energetic and painstaking labours, I have ventured to employ his name to distinguish this species of *Ctenoptychius*.

CTENOPTYCHIUS PECTINATUS, Ag.

A second species of *Ctenoptychius* has also been found at Aust, and forms a part of the collection of Mr. Ord, of Bristol. It is ·2 inch across the crown, and has a depth from the upper edge of the crown to the base ·15 inch. The crown is composed of about 12 denticles, the tips of which extend almost in a straight line; at the apex the denticles terminate in short pointed cones. Towards the body of the tooth these speedily coalesce and form plications extending more than half the distance towards the base; they form a concave surface anteriorly, the base becoming thicker and convex. The two outermost denticles, stronger than the remainder, are continued in a semicircle, and converge towards the base. The whole of the exposed surface is covered with a black, shining enamel.

In the third volume of the 'Poissons Fossiles'*, M. Agassiz describes and figures under the name of *Ctenoptychius pectinatus*, some small teeth obtained from the Burdie-House Limestone. The specimens figured present very considerable variations in form, but are each characterized by the denticles forming the crown of the tooth being less distinctly separated towards the apex, and the points, instead of extending vertically, as in *C. apicalis*, diverge or radiate from the centre, somewhat in the form of a fan. The beautiful little specimen from Aust agrees sufficiently well with this description to warrant its inclusion in the same genus and species. Its more rounded basal termination is the most striking point of divergence, *C. pectinatus* having a more contracted stem-like or prolonged basal portion.

CLADODUS CURTUS, Davis. (Plate XXII. fig. 9.)

This tooth offers some peculiarities which give it a distinctive character. It is imbedded in the matrix; and on the lower part it is slightly imperfect. It consists of a wide and thick base, from the centre of which springs a cone-shaped cusp. On either side the central cone there are indications that at least one secondary cusp has existed. The bony structure is very dense, and now of a deep brown colour. The length of the base is ·4 inch; and the height of the central cone is ·3 inch. The latter is rather less

* Page 100, tab. 19. figs. 2, 3, 4.

than ·2 inch in diameter, and it ends in a rounded apex; rising from the body of the tooth, it first curves a little outward and backward, and then again bends forward, the end projecting, as shown in fig. 10*a*, Pl. XXII. It appears to be thin in proportion to its width, and has quite a tongue-shaped appearance. The surface of the part of the tooth forming the cone is deeply indented with numerous pituoles. The tip is smooth and is covered with a thick coating of ganoine. The basal line of the lower portion of the tooth is curved inwards from each lateral extremity; and from the cone the tooth swells with a well-rounded forward curve to the base. Near each lateral extremity of the base a part has been broken away with the matrix. The portion left exhibits the base of a secondary denticle or cone, in the centre of which is the cavity which ascended towards its point. The secondary denticles were placed forward in comparison with the principal centre one, and were rounder in section.

This specimen more resembles Agassiz's species *C. marginatus* than any other; it may be easily distinguished, however, by the absence of the deeply striated surface which characterizes the latter and by its shorter base. I suggest the nomen triviale *C. curtus*.

EXPLANATION OF PLATE XXII. figs. 1–9.

Fig. 1. *Hybodus austiensis*, Davis.
2. *Hybodus punctatus*, Davis.
2*a*. Transverse section.
3. *Nemacanthus monilifer*, var. α.
3*a*. Transverse section.
4. *Nemacanthus monilifer*, var. β.
4*a*. Transverse section.
5. *Nemacanthus minor*, Davis.
5*a*. Portion of spine, magnified.
5*b*. Transverse section.
6. *Palæosaurus Stricklandi*, Davis.
6*a*. Tooth, magnified.
6*b*. Transverse section, nat. size.
7. *Sphenonchus obtusus*, Davis.
7*a*. Ditto, magnified.
7*b*. Antero-lateral form.
7*c*. Posterior view.
7*d*. Postero-lateral form.
8. *Ctenoptychius Ordii*, Davis
8*a*. Longitudinal section.
9. *Cladodus curtus*, Davis.
9*a*. Longitudinal section.

Discussion.

Prof. Seeley remarked on the curious survival in the Aust deposit of Palæozoic types of fishes mingled with forms peculiar to the Mesozoic as offering a parallel to the mixture of Palæozoic with Secondary Mollusca in the Upper Trias of the Austrian Alps. He stated that *Sphenonchus* always occurs on the head of Hybodont fishes in the Secondary rocks.

Mr. Tawney thought the Palæozoic forms in the Aust bed are fossils derived from the Carboniferous strata, and not, as Prof. Seeley contended, surviving types.

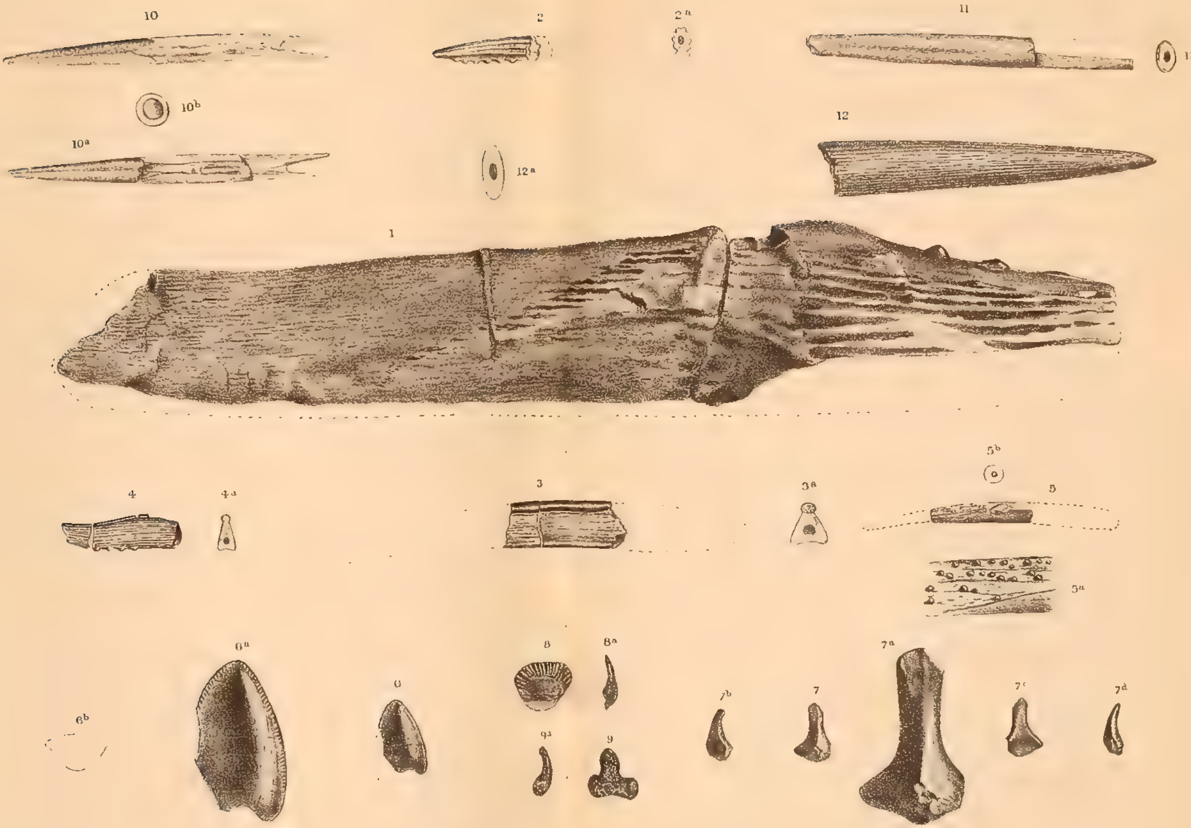
Mr. Longe stated that there is a great difference between the contents of the bone-bed at Garden Cliff at Westbury and Aust Cliff respectively. He thought the fossils in the bone-bed do not belong to the period at which the materials were accumulated.

Mr. Ussher thought that the working-out of the Rhætic beds might afford evidence of the unconformities due to changed conditions of deposit. He alluded to an appearance of unconformity between Rhætic and Trias at Newark, where a thin band of derived fragments occurred at the base of the former.

Rev. H. Winwood argued against the theory of the bone-bed being a *remanié* bed from the fact of the delicate fossils in it not being waterworn.

The President thought that most of the fossils at Aust Cliff and Westbury are not *remanié*, but are of the true Rhætic age; but some Carboniferous forms are undoubtedly derived. The specimens of *Ceratodus* were not at all worn. The form called *Sphenonchus* is certainly the head-spine of *Hybodus*, as proved by specimens from Lyme Regis.

The Author stated that the details that he had given represented the examination of only three collections, and that there yet remained much work to be done in this field.



A. S. Foord del et lith

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FISH REMAINS FROM THE AUST BONE-BED
AND THE COAL-MEASURES

33. *On* Anodontacanthus, *a* new Genus *of* Fossil Fishes *from the* Coal-measures; *with* Descriptions *of three* new Species. By James W. Davis, F.G.S. &c. (Read May 11, 1881.)

[Plate XXII.]

The spines which form the subjects of the following descriptions are from the West-Riding Coalfield in Yorkshire, and the Ironstone occurring in the Lower Limestone series near Edinburgh. A stratigraphical description of the Cannel Coal at Tingley, from which the first two species have been obtained, may be consulted in the Quarterly Journal of the Geological Society issued for February 1880, page 56.

The three species of Ichthyodorulites forming the subject of this paper are the only specimens of which I have cognizance possessing their peculiar characteristics. In some particulars they resemble the genus *Pleuracanthus*; they are composed of a strong, close-grained, fibrous substance. Their general form is also similar to that of the Pleuracanths: the internal cavity is terminal at the basal extremity; and the walls become thinner near the base in comparison with the remainder of the spine; the method of implantation in the body of the fish must also have been the same. The great distinguishing feature between the two rests in the absence in this genus of any form of denticulation. In the Pleuracanths there are two rows of denticles either along each lateral surface or on some portion between the lateral and posterior lines. Whether this may be a sufficient distinction to necessitate a second genus, or further discoveries will prove that it must be included in the genus *Pleuracanthus*, remains to be seen; but for the present it may be better to consider it as a distinct genus, for the following reason: hitherto remains of the fish *Pleuracanthus*, where found in even tolerable perfection, as in the Stone-coal of Bohemia, have always had associated together the three-pronged teeth of the so-called *Diplodus*, and a spine, the latter more or less straight, but always possessing, in one situation or another, two rows of denticles. From Tingley, where the spines under discussion have been obtained, I have several slabs of Cannel Coal covered with a mass of cartilage full of the mosaic-like, minute, rhomboidal, bony centres characteristic of *Pleuracanthus*, with numbers of teeth, and occasionally a spine *in situ*; but in all cases the spine has been denticulated. So far all the evidence goes to show that the spines of *Pleuracanthus* were armed or ornamented by these denticular appendages; there is a possibility, however, that a specimen may be found with a spine without denticles in association with undoubted *Pleuracanthus*-remains; and should that happen, it will be necessary to modify the character of the genus so as embrace this one. Until such evidence is forthcoming, it may be regarded as a distinct genus, for which the name *Anodontacanthus* may not be inappropriate, signifying a toothless spine.

1. Anodontacanthus acutus, Davis. (Plate XXII. fig. 10.)

Spine. Length 2·5 inches, breadth ·2 inch. The spine is straight, and gradually tapers to a point; there are no denticles; and the surface of the spine is uniformly covered with little pittings, giving an appearance of reticulation. The walls are about one fourth the diameter of the spine in thickness; there is an internal cavity with a wide open termination at the basal extremity, the walls as they approach the base becoming much thinner. The cavity extends along the interior of the spine almost to its apex. The spine has every appearance of having originally been circular in form. It has, however, become somewhat crushed along the basal or weaker portion of the spine since its deposition. The specific designation *acutus* expresses its pointed character.

Locality. Cannel Coal, Tingley, Yorkshire.

2. Anodontacanthus obtusus, Davis. (Plate XXII. fig. 11.)

A spine from the same locality and horizon as the one already described is of larger dimensions and different form; the basal end is broken off; the remaining portion is 2·5 inches in length, and the diameter nearly 0·3 inch. Judging from the proportions of the spine preserved, it is probable that, including the missing portion, its length would be 3·50 inches when perfect. The surface is uniformly covered with minute longitudinal striations, which towards the apex become broken up into small pore-like indentations, the latter being finer than in the smaller species. The portion of the spine preserved maintains a uniform thickness to within an inch of the apex, where it becomes slightly contracted, and ends in a broad, flattened, obtusely rounded extremity, 0·2 inch across. The body of the spine is oval in section, with an internal canal occupying one third of its diameter. The spine differs from the one described before in its greater size, oval form in section, extremely broad apical termination, striated surface, and in the greater thickness and strength of its walls. All together these differences appear sufficiently great to render necessary a separate specific designation; and I propose to give it the name of *A. obtusus*, in reference to its obtusely-pointed extremity.

Locality. Cannel Coal, Tingley, Yorkshire.

3. Anodontacanthus fastigiatus, Davis. (Plate XXII. fig. 12.)

Spine imperfect, the base absent; part preserved 2·4 inches in length, extending from the point, apparently half the length of the spine, the lateral diameter greatest, being 0·4 inch. It is oval in section, least diameter between the anterior and posterior faces being 0·2 inch; there is a central cavity, circular in section, which extends towards the point. From the largest diameter of the spine, it becomes gradually smaller, and ends in a somewhat worn-looking point. The whole of the surface is covered with longitudinal striæ, most distinct near the basal extremity, anastomosing and becoming gradually less numerous towards the point, where the striæ have disappeared and the spine is smooth.

This specimen is evidently closely related to the two species already described from the Cannel Coal, though it varies somewhat in form. It is larger and stronger in appearance; as compared with the others it is very broad towards the base, and contracts in diameter more rapidly to the point. It is oval in section, in this particular resembling *A. obtusus*, whilst it differs from *A. acutus*, which is round; all the three agree in being straight, ending in a more or less pointed apex, and in the absence of denticles. The spines are of the same dense structure in each; and the form of the internal cavity appears to be similar. In reference to its tapering form, I suggest the specific name *fastigiatus*.

Locality. Blackband Ironstone at Loanhead, in the Middle Limestone series near Edinburgh. The specimen has been sent to me by Mr. W. Tait Kinnear of that city.

EXPLANATION OF PLATE XXII. figs. 10–12.

Figs. 10, 10*a*. *Anodontacanthus acutus*, Davis.
Fig. 10*b*. Transverse section.
11. *Anodontacanthus obtusus*, Davis.
11 *a*. Transverse section.
12. *Anodontacanthus fastigiatus*, Davis.
12*a*. Transverse section.

34. *On certain* Quartzite *and* Sandstone Fossiliferous Pebbles *in the* Drift *in* Warwickshire, *and their probable* Identity, *lithologically and zoologically, with the true* Lower Silurian Pebbles *with similar* Fossils *in the* Trias *at* Budleigh Salterton, Devonshire. By the Rev. P. B. Brodie, M.A., F.G.S. (Read May 11, 1881.)

Special interest and some little difficulty attaches to the history and origin of certain quartzite and other pebbles in the Drift in a limited portion of the Midland Counties, which it is desirable, if possible, to determine. With this object I beg leave to lay a few more additional particulars before the Society, which will form a supplement to my previous paper in the Quarterly Journal, vol. xxiii. p. 210, 1867. It seems probable that the Keuper sandstones and marls in the more central parts of England were at one time much thicker, before denudation had reduced them, and that the pebble-beds existed in them as at Budleigh Salterton, and were afterwards broken up and the pebbles (like the flints of the Chalk) scattered about in all directions by powerful currents of water, helping to form a large proportion of the Drift in this and other parts of the Midlands. In a short notice in the Geological Magazine (July 1878), Mr. S. G. Percival supposes that the quartzose and many other pebbles in the Drift of the Midland Counties were originally derived from the Bunter conglomerate. This may be probable in some slight degree; and Mr. Jennings, in the Geological Magazine (May 1878, No. 167), states that he has found *Orthis redux* (*budleighensis*) in a supposed Bunter pebble near Nottingham, where a careful search should be made for other fossils which may occur there *in situ*, both in the Conglomerate and the Drift—viz. the gigantic *Lingulæ* so characteristic of the lower Silurians in Normandy, some of which I have already detected in the Drift at Rowington. If it can be shown that these pebbles in the Drift were originally derived from the Bunter, the latter must have been broken up before they were deposited in this newer portion of the Trias; then comes the question, Whence were these pebbles derived in the first instance, before they were washed, first into the Bunter (helping to form the Conglomerate), and afterwards into the later New Red Sandstone, as they certainly were, in Devonshire and other places?

The fossils found in these pebbles here and elsewhere show that many belonged to Palæozoic rocks, as evidenced by *Orthis budleighensis*, *Lingula Leseurii*, *Trachyderma serrata*, and some others given in the list at the end of this paper. Some of these, especially the *Lingulæ*, are species which as yet have not been noticed anywhere *in situ* in this country, but are peculiar to Normandy and Brittany, and were determined by the late Mr. Salter. Mr. Pengelly (Geol. Mag. No. 167, 1878) thinks that the occurrence of *Orthis budleighensis* in the altered quartz rock (Lower Silurian) of Gorran Haven, Cornwall, shows that some of the Budleigh pebbles were derived from there, which may be the case so far as regards the Devonian area, but would hardly account for their presence so much further to the north-east, in some parts of the Midland Counties for example.

Therefore I suggested a more northerly or north-easterly extension of Old Silurian rocks, in which view my late lamented friend Professor Phillips concurred. This would bring them much nearer to that portion of England now forming the Midland District; and the destruction of those ancient palæozoic deposits may have largely helped to supply the Bunter with pebbles, which were in later times, by the denudation of the latter, washed into the New Red Sandstone then forming. This, again, in its turn, was greatly attenuated, and the pebbles, much reduced in bulk, finally distributed, with many others derived from rocks of diverse ages and from all parts (north, south, east and west, notably from the north), as Drift.

With reference to the Bunter Conglomerate on the northern edge of Cannock Chase, Professor Bonney, in a paper in the Geological Magazine for September 1880, concludes, from a careful comparison of the quartzite at Loch Nearn in Scotland, that many of the Staffordshire Bunter pebbles were derived from the north-west of Scotland. Other and different quartzites, he says, resemble more closely those of Budleigh, the Lickey, and Hartshill. He found *Orthis budleighensis* in a pebble at Rugeley which was identified by Mr. Etheridge, and was, he states, lithologically and zoologically identical with the Cornish and Budleigh specimens. He also noticed a *Rhynchonella*, and probably *Orthis calligramma*. In Mr. Percival's collection of pebbles from the Drift at Moseley, Birmingham, in the Jermyn-Street Museum, the following fossils are recorded—*Orthoceras*?, *Cleidophorus amygdalis*, *Orthis budleighensis*, *Stricklandinia lyrata*, *Spirifera disjuncta*, *Glyptocrinus*, *Petraia bina**. Professor Bonney is of opinion that the Lickey largely contributed to the Bunter pebbles about Birmingham and Bromsgrove. I quite agree with him in thinking that none of the Midland-Counties pebbles came from South Devon, and with Prof. Hull that very many have a northern origin; but there many others in certain places, and notably in the area referred to in this paper,

* Some time since, I looked over a miscellaneous collection of rocks presented by Messrs Allport and Percival to the Midland Institute, obtained by them from the Drift in the neighbourhood of Birmingham, chiefly from Moseley and other places adjacent. There are many igneous and metamorphic rocks, basalt, granite, syenite, and hard crystalline pebbles, including agates, all of which occur at Rowington. The fossiliferous rocks are chiefly Carboniferous, including chert with encrinite stems, probably from Derbyshire, several shells and corals and coal-plants. There are few (if any) Llandovery species. There are some *Orthides*, some of which occur in a dark-grey boulder very like the Snowdon rocks. There are only a few quartz pebbles similar to those described in this paper; but I observed among them *Orthis budleighensis* and *Trachyderma serrata* of large size and well preserved, but certainly, taking the whole collection, not so numerous as in the Drift in this district.

which must have had a different origin. Very likely the altered Llandovery Sandstone (quartz rock) of the Lickey contributed many of the pebbles in this Drift, though it would be almost impossible to determine the source of all the quartz pebbles in the latter; I have, however, not yet detected a single well-defined Llandovery species in any of them in this district; and a very considerable number, if not a majority of the fossils in the pebbles I have obtained are decidedly of Lower Silurian origin; so that in a direction south of Birmingham and towards Warwick and Stratford-on-Avon the tendency evidently seems to be that pebbles of lower palæozoic age predominate; and the lithological and zoological resemblance which they bear to the pebbles of this date at Budleigh is sufficiently close to lead to the conclusion that they are in all respects identical and were derived from some Old Silurian rocks at a greater or less distance, and so far had a common origin. Originally, of course, they must have come from their parent palæozoic rock wherever it was, by the wear and tear of which, by the action of waves and currents and other processes of denudation, in the course of ages they became pebbles, and may have been in the first instance, perhaps, washed into the Bunter and have helped to form a portion, greater or less as the case might be, of its conglomerates in certain places. When this was in its turn fractured and denuded, some of these pebbles may have been afterwards redeposited in the New Red Sandstone, not everywhere, but locally, as at Budleigh in Devonshire, and parts of Warwickshire*. When the latter was also largely denuded, these Old Silurian bouldered remnants were finally scattered about and mingled with the Drift. If not derived from the Bunter or the New Red Sandstone they must have come directly from the relics of some ancient Silurian formation which was still in existence, and was finally but partially broken up at a more or less distant period, thus helping to add largely to the widely accumulating, often sifted and re-formed Drift.

In a redistributed and miscellaneous superficial deposit of pebbles and other débris, like that of the Midland Counties in the districts referred to, it would, I think, be incorrect (at least we have not sufficient evidence as yet) to infer that most of the quartzite and other pebbles are derived from the Bunter. A large majority of these are more or less consolidated quartzite; and I have one pebble of quartz with an obscure impression of a shell, which reminds me of the Cornish Lower Silurian rock at Caerhayes. The most abundant are grey and brown, more or less striated, consolidated sandstone boulders, varying in size and sometimes of a deep red colour; and these agree lithologically with the Budleigh pebbles containing

* Although, with the exception of the Lower Keuper sandstone at Budleigh, there are no pebbles elsewhere found *in situ* in the New Red Sandstone, there is no reason why they should not have occurred in certain places in other directions in the same formation, either in the Upper or Lower Keuper. In the Midland Counties the upper division has here and there undergone very extensive denudation; or possibly pebble-beds may still exist in the New Red which have not yet been discovered.

certain well-known Silurian species and some of the rock specimens I have from Normandy. In fact placing the majority of the Warwickshire Drift pebbles in my collection side by side with those from Devonshire and France, it would be impossible to separate them, the character of the rock being identical, and the fossils, where present, the same. This is a point of much interest, and while fossiliferous pebbles are on the whole rare (though, of course, very many must have been overlooked), there are many which have the same mineralogical character, and really form a considerable portion of the gravels, and were, no doubt, derived from the same source and originally belonged to a formation of the same age. With the exception of a few Carboniferous fossils and others of later date a very large percentage belong, as it appears, to the older Silurian rocks, and wherever they may have occurred *in situ* must have been originally derived from them. The absence, apparently, of Llandovery fossils is remarkable, and seems to show that a very small proportion of the Drift in this district had come from the Lickey within sight and not so very far off. In a list of fossils from the Bunter conglomerates near Cannock Chase, Mr. W. Molyneux*, F.G.S., on the authority of the late Mr. Salter, assigns all the species to Mountain-Limestone and Upper Silurian (May Hill sandstone, Llandovery) groups, and not one Lower Silurian form occurs; but Professor Bonney records *Orthis redux* (*budleighensis*) † from the same district on the authority of Mr. Etheridge. Mr. Davidson‡ is of opinion that the majority of the Brachiopoda in the pebbles at Budleigh are Devonian, which predominate; but the Lower Silurian are sufficiently numerous and well preserved to have enabled Mr. Salter || to determine and identify a considerable number with certain species, giant *Lingulæ* and others, peculiar to the district of May and Gehard, (Armorican sandstone) in Normandy.

The small collection of Lower-Silurian fossils which I possess, the result of several years' work, from a limited area of the Midland District, must have been derived from a much nearer source than Devon or Cornwall; and Professor Bonney, in the same paper, justly observes that, as from physical considerations it is almost impossible that Cornish pebbles could have made their way into the country round Cannock Chase, the only possible inference is a nearer one by a further extension to the north-east of the old Silurian strata with their fossiliferous sandstones and quartzites. The idea that they can have been derived directly from Normandy is, of course, out of the question; and Mr. Davidson also contends for an extension, as I do, of Silurian rocks in the Channel and nearer to Devonshire as a

* Proceedings of the Dudley and Midland Geological and Scientific Society, 1877, p. 139.

† Mr. A. H. Atkins, B.Sc., one of the masters of King Edward's School, Birmingham, has lately found *Orthis budleighensis*, *in situ*, in one of the Bunter pebble-beds, at Kinver Edge, near Stourbridge, which is another instance of the presence of this species in the lower division of the Trias. I recognized the species at once, and Mr. Davidson has since confirmed it.

‡ Quart. Journ. Geol. Soc. vol. vi., February, 1870, No. 101.

|| Quart. Journ. Geol. Soc. vol. ii., August, 1864, No. 79.

probable source of the Budleigh pebbles which contain fossils of that date. The extension of this area of ancient rocks, or, indeed, of any geological age, is never improbable when we consider the enormous amount of denudation which all great formations have at one time or other undergone. I have made some additions to the Lower-Silurian fossils I have detected in the Warwickshire Drift since the publication of my former paper on this subject in the Journal of the Geological Society (vol. xxiii. p. 210, 1867); *Orthis redux* and *Lingula Leseuri* were determined by Mr. Woodward some years ago; *Lingula*, n. sp., by Mr. Davidson, and the remainder by Mr. Etheridge, who has been kind enough to examine them; and I here give the entire number, with the additional species, on his authority:—

Orthis budleighensis.
—— Valpyana.
Lingula Leseurii, n. sp., *Davidson.*
Spirifer antiquissimus?
—— Davidis?
Rhynchonella sp.
Modiolopsis lirata.
—— sp.
Lyrodesma cælata?
Ctenodonta Bertrandi?
Arca Noranjoana?
Palæarca secunda.
Trachyderma serrata.
Calymene Tristani.
Homalonotus, portions.
Fucoids, one or two branching forms.

Orthis budleighensis is very abundant and characteristic. One of the *Lingulæ* determined by Mr. Davidson is, he says, a new species and totally unlike any of those from Budleigh. The Annelid *Trachyderma serrata* is frequent and generally in good preservation. The total number of Lower-Silurian genera and species figured and described by Salter from the pebbles at Budleigh Salterton is twenty-four; and there are several diligent collectors of these fossils in Devonshire. From the Midland Drift, in a limited space and with less facilities for obtaining them, I have procured sixteen, leaving only a difference of eight in favour of Devon—which is somewhat remarkable, considering the much better opportunities for collecting them in the West. At present, I believe, this is the largest number of Lower-Silurian fossils of the age, probably, of the Bala and Lower Llandeilo formations, hitherto observed in the Midland Drift. This fact too, I think, strengthens my argument in favour of more extensive ramifications of old palæozoic rocks in a north or north-easterly direction; and these, when broken up, would furnish ample materials coming from different areas to supply the fossiliferous pebbles referred to. No doubt this list would be largely increased if the road-heaps, collected chiefly from the fields, could be more diligently searched; for many fossiliferous pebbles must be overlooked.

Mr. Walter Keeping, in an interesting paper * on the Upware and Potton Greensand pebble-beds, observes that "some of the quartzites are like those of the New Red Sandstone pebble-beds, and were probably thus derived." He accounts for the presence of other older palæozoic pebbles by the supposition that they were derived from a great palæozoic ridge extending northwards towards Cambridge.

* Geological Magazine, No. 195 (New Series, No. 19), Sept. 1880, p. 414.

From this source at an earlier period the Upper and Lower Triassic pebbles were, as I have inferred, probably derived; and hence it formed the supply of a large proportion of the Midland Drift in the districts referred to in this paper. Mr. Etheridge suggested the possibility of the Wenlock Limestone, lately noticed in a boring at Ware, dipping to the south. This surmise, Mr. Keeping says, has since proved to be correct; and therefore a further extension of ancient Silurian and Cambrian rocks northwards is still more probable.

This denudation of these old rocks may have come to a close during the Cretaceous or even some later period, when they finally disappeared beneath the sea, having been going on for ages, perhaps commencing at a date somewhat anterior to the deposition of the Bunter. There are, perhaps, few geological problems more difficult to solve than the history (range, distribution, and origin) of these latest Pleistocene deposits, such as clays, till, gravel, and sands under the name of Drift, which are so widely spread and often composed of such heterogeneous materials. Where made up for the most part of formations present *in situ* in the immediate neighbourhood or not very far off, the solution is comparatively easy; but where they are mainly derived from a great distance, perhaps here and there from foreign sources, as some of our Midland Drift may be, it is very puzzling and extremely difficult to determine whence they originally came and by what means they were transported. Though many able papers have been written upon this subject, much yet remains to be done both here and elsewhere before definite and satisfactory results can be obtained.

[*Note*, July 21.—It has since been determined that some of the Brachiopoda belong to the Caradoc.]

Discussion.

The President remarked that the subject was a difficult one, but the species, as stated by Mr. Brodie, were no doubt correct. At Budleigh Salterton it was easy to tell whence many of the pebbles had been derived; but in the Midland counties it was most difficult.

Mr. Ussher said that the occurrence of the same fossils did not prove that the pebbles were from the same area, and that the Drift of the paper was not quite clear from its title.

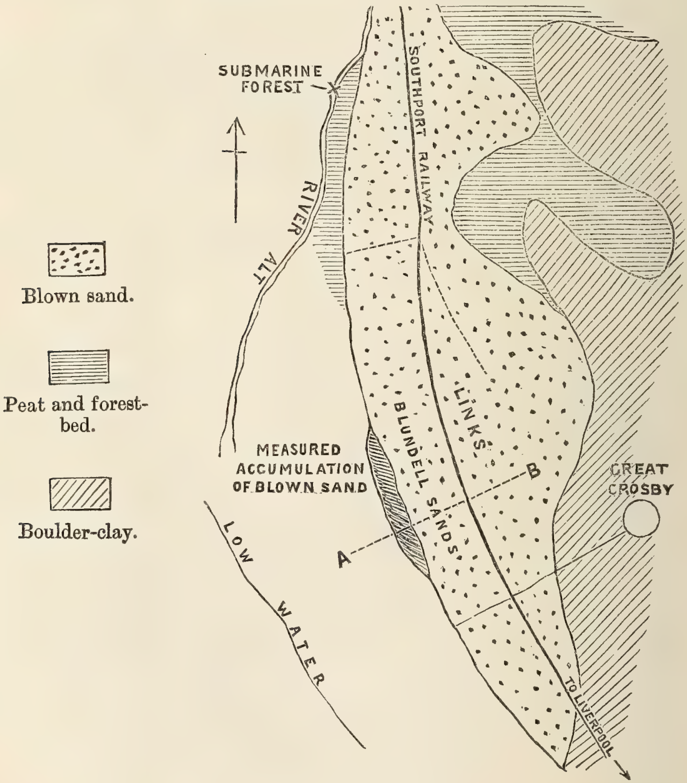
Prof. Bonney stated that the author had not expressed this opinion in his paper; he thought it a most valuable addition to our knowledge, and was glad that such a contribution had been evoked by his own slight paper. He thought it almost certain that there were two sources for the quartzites, and that all the fossiliferous specimens could not have come from the Lickey, as some had been found at Nottingham. Probably ancient rocks had extended to the north-east of England, beyond those discovered in borings at Northampton, and to the north-east of those exposed at Charnwood.

35. *The* Date *of the* last Change *of* Level *in* Lancashire. By T. Mellard Reade, Esq., C.E., F.G.S., F.R.I.B.A. (Read April 6, 1881.)

In estimating geological time the difficulty always lies in getting a reliable unit to measure with. Having surveyed and mapped out, on a scale of 6 inches to the mile, the whole series of Postglacial deposits between Liverpool and the mouth of the river Douglas, I have often asked myself, Can the age of any of these deposits be translated from mere sequence into years? Observation has led me to believe that an approximation may be made in the case of the blown sand; and this, as I will presently show, bears upon the title of my paper.

A reference to the map (1 inch to the mile) and section, figs. 1 & 2,

Fig. 1.—*Sketch Map of the Coast at Blundellsands, near Liverpool.* (Scale 1 inch to the mile.)



and to those accompanying my paper on the Post-Glacial Geology of Lancashire and Cheshire, in the 'Proceedings of the Liverpool Geological Society,' 1871–2, will explain the order and sequence of the deposits; and it will be seen that the last movement of the land in Lancashire was downwards*. Submarine forests at the Alt mouth, the Rimrose brook, the Liverpool and Garston docks show that subsidence has taken place; and (which is perhaps quite as good evidence) sections of stream gullies, cut in the Boulder-clay and filled with recent silt, at levels far below high water, are frequently met with in dock-excavations.

Upon the superior peat- and forest-bed, which is an extension inland of the submarine forests, rests, as on a platform, some 22 square miles of blown sand, in some cases rising 75 feet above Ordnance datum, and estimated by me to be at least 12 feet in average depth.

This deposit is shown in my map, as well as in that prepared by the Geological Survey, by yellow dots; it varies in width at different localities, its maximum being at Formby, where it reaches 3 miles inland. It is quite evident that the whole of this Æolian deposit is an accumulation subsequent to the last subsidence of the land; therefore, if we can calculate the time it must have taken for the deposit to form, we shall be in a position to determine the *least* time that can have elapsed since the subsidence.

The whole of the blown sand has been derived from the shore between high- and low-water marks, but principally from between high water of springs and neaps when the shore is dry. On a windy day it is very curious to see the streaks of sand rushing over the shore, even when it is damp, shining like rays of a lighter colour pencilled over a dark ground. The shore is very flat, being in places more than a mile wide between high- and low-water marks of spring tides; so that the conditions for the generation of subaerial sand can hardly ever have been more favourable than they are now.

In May 1866 I set out a plot of land at Blundellsands, in Burbo Bank Road North, for building-purposes; it had a frontage of 350 lineal yards to the sea, the western boundary being the then high-water mark of spring tides. In 1874, for the purpose of enclosing the said plot, I had to remeasure it to define the boundary, when I found that high-water mark was considerably beyond the western boundary, and that the sand had gained upon the sea. An open wire fence was then put up on the original high-water mark, when measurement showed that there were 15 yards of land in front of it at one end, and 5 yards at the other. The high-water mark of springs had, in fact, receded to that extent. I estimated the deposit of sand that had taken place in the eight intervening years at an average of 10 yards wide along the whole frontage and 2 yards deep. Allowing 1 yard more in depth for sand that may have been

* At Meols, in Cheshire, on the opposite side of the Mersey estuary, was a Roman station; and the land is now only a few feet above high-water; therefore the land cannot have *risen* since the Roman occupation.

blown over the top, which I am convinced is a large estimate, as very little sand blows on to Burbo Bank Road North, the eastern boundary of the plot, we shall thus have $350 \times 10 \times 3 = 10500$ cubic yards of sand deposited in eight years on a shore-frontage of 350 lineal yards—or 3·75 cubic yards per lineal yard of frontage per annum.

Taking this as my unit of measure (and it is an exceptionally large one), I find, for the 16 miles of coast forming the western boundary of the deposit, it will give 105,600 cubic yards per annum as moved by the wind; and dividing the 272,588,800 cubic yards contained in the 22 square miles, 12 feet thick, it will give 2580 years as the age of the whole deposit of blown sand if accumulated at the assumed rate.

Since these calculations were made, I have lately tested their accuracy in another manner. There is another plot in Serpentine Road, having a sea-frontage of 243 lineal yards, and containing about 6500 square yards. Serpentine Road was made from my sections and under my superintendence in 1866; so that I had every opportunity of ascertaining the respective levels. Taking every thing into consideration, I estimate that there has accumulated over its whole surface an average depth of less than 2 yards of sand (very little blows across the road); so I think we may fairly take an average depth of 2 yards as representing the quantity of sand blown off the shore from a frontage of 243 lineal yards. This, extended over fourteen years, gives 3·81 cubic yards of sand per lineal yard of frontage per annum.

It is quite evident that the sand cannot accumulate faster than it sweeps off the shore; but at other points on the coast the sea is

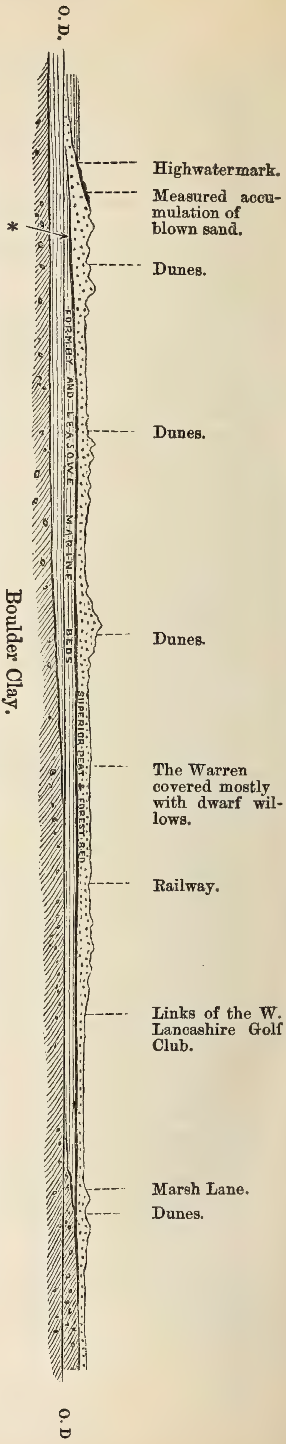


Fig. 2.—*Section along the line A–B in* Fig. 1.

* At the Alt mouth this continues under the Sand-dunes and reappears on the shore as a submarine Forest-bed. (See Map.)

gaining on the land; therefore what is deposited in front of the sand-dunes is again swept away, and all that goes to the accumulation is that which is blown over the tops of the hills or sand-cliffs.

This will also be the case where the coast-line is stationary. Again, the high sand-dunes form a barrier that the sand cannot so readily surmount, the practical effect being that, the bases being swept by the tide, and the angle of repose remaining constant, less sand travels inland the higher they grow. At the mouth of the Alt there is a very extensive bank at low water swept by the north-west wind; but the sand does not accumulate, as it is blown into the river Alt and washed out seawards again. The land on which the Altcar rifle-range is situated has, in fact, as a protection to the river, been gained from the sea by the erection of artificial obstructions, against which the sand accumulates. This accumulation has now practically ceased; and the river and the sea combined are eating into the land by the Crosby lighthouse, and making sad havoc with the submarine peat- and forest-bed.

On referring to the map it will be seen that the blown sand is narrowest at this point, though the conditions are very favourable for its development, had the river Alt not intervened.

If, then, it be conceded that the last change of level in South-west Lancashire was a downward one, I think the facts and calculations I have had the honour to lay before you pretty clearly prove that it did not take place within the last 2500 years.

Discussion.

The Chairman (Mr. Hulke) remarked upon the economic as well as scientific interest of the communication from the proved increase of land in the area.

Mr. De Rance, who had surveyed the district described by Mr. Reade in his paper, could corroborate many of the author's conclusions, especially by the finding of Roman coins on the surface of the marsh land and by a Roman bath only 5 feet above high-water mark.

Prof. Judd stated that Mr. Reade's conclusions were entirely in accord with the most recent researches concerning the supposed changes in the level of the shores of the Firth of Forth since Roman times.

The Author stated that at Hoylake, in Cheshire, numerous Roman remains belonging to a Roman encampment a few feet above high-water mark prove that no appreciable downward movement has taken place since Roman times. He thought the actual period required for the formation of the blown sand was probably nearer 5000 than 2500 years.

36. *On a* NEW SPECIES *of* PLESIOSAURUS (*P. Conybeari*) *from the* LOWER LIAS *of* CHARMOUTH; *with Observations on* P. MEGACEPHALUS, Stutchbury, *and* P. BRACHYCEPHALUS, Owen.

By W. J. SOLLAS, M.A., F.R.S.E., F.G.S., &c., Professor of Geology in University College, Bristol. *Accompanied by a* SUPPLEMENT *on the* GEOGRAPHICAL DISTRIBUTION *of the* GENUS PLESIOSAURUS, by G. F. WHIDBORNE, Esq., M.A., F.G.S. (Read May 11, 1881.)

[PLATES XXIII. & XXIV.]

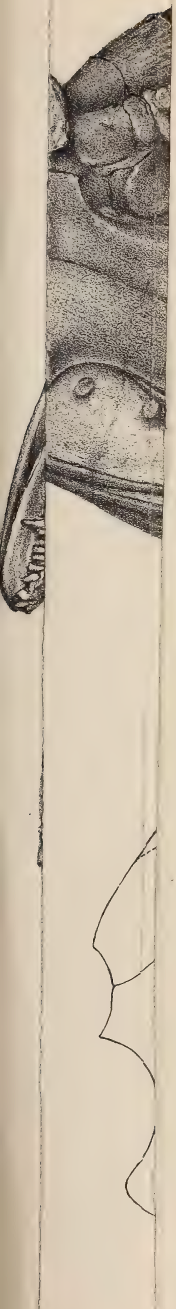
THE nearly complete and very fine specimen of *Plesiosaurus* (Pl. XXIII. fig. 1) which forms the subject of the present paper is the latest addition to the already large collection of fossil reptiles preserved in the Bristol Museum.

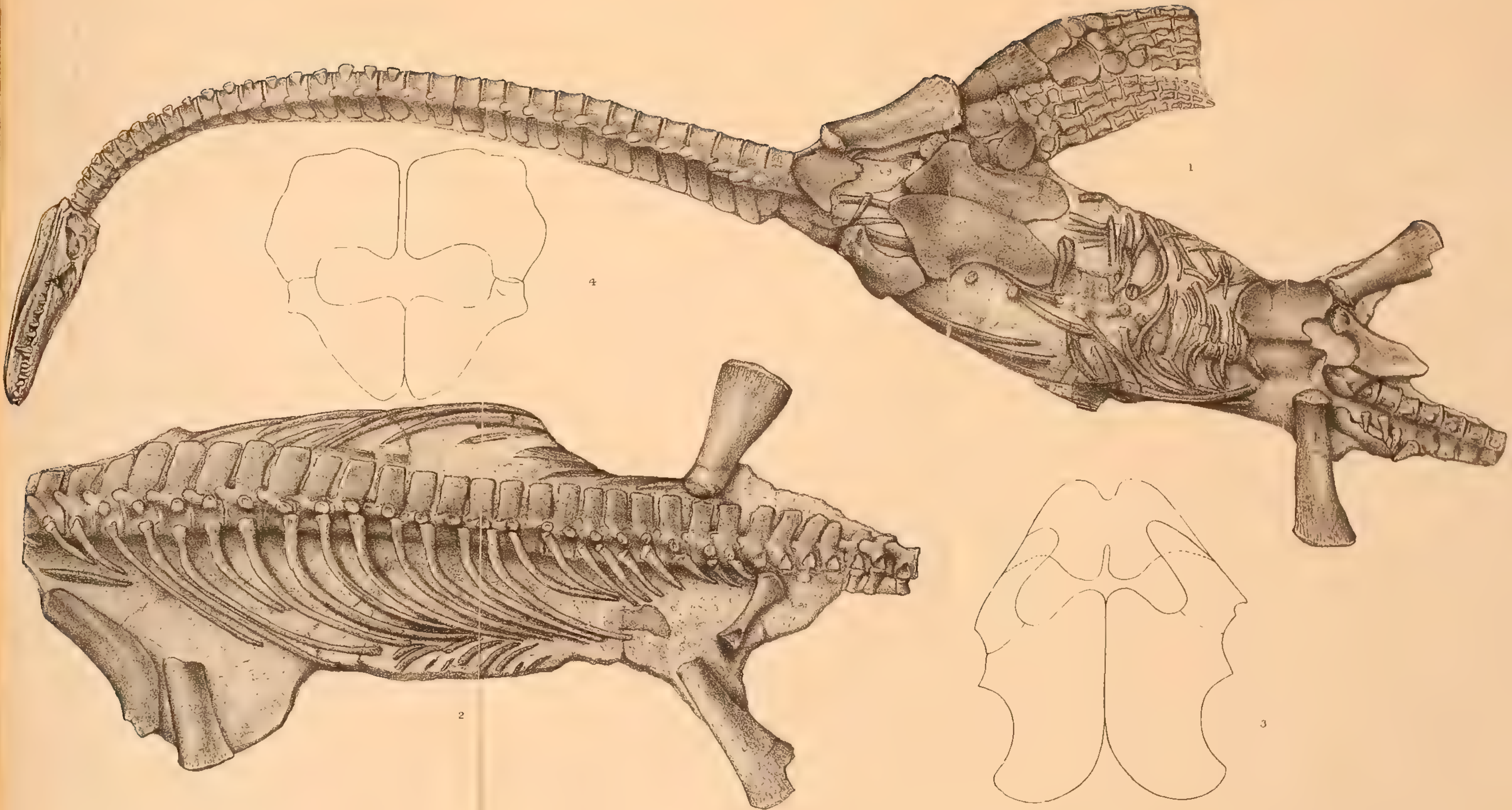
It was found over a year ago, by Samuel Clarke of Charmouth, on the north-west corner of Blackven Water, half a mile west of the river Char, where it lay in a "table-ledge" of the Lower Lias, some seven feet above the "boulder-bed." From its position and the species * of Ammonite still associated with it, we may conclude that its geological horizon is that of the zone of *Ammonites obtusus*.

From the pectoral to the pelvic girdle it is imbedded in a layer of hard impure limestone, thick enough to hold the parts securely together, but at the same time thin enough to let the skeleton be seen on both sides, dorsal as well as ventral. The head and neck were preserved chiefly in shale; so that, to ensure the safety of the neck, it has been found necessary to imbed it in plaster; but the head, being filled in and about with limestone, has been left free, and can be turned about, handled, and examined on all sides.

The ventral surface of the fossil (Pl. XXIII. fig. 1) is exposed on the upper surface of the imbedding limestone; the coracoids lie side by side nearly in the position they would have occupied in the dead animal lying on its back, except that they are slightly displaced towards the left side; the left pubis and ischium are also nearly in position; but the corresponding bones of the right side have been pushed to the left, so as to underlie them; the femora, which are all that is left of the hind limbs, remain on their proper sides, extended outwards and backwards. The fore limbs have been considerably displaced; for though that of the left remains on its own side, the palmar surface of its hand looking upwards, that of the right has been completely crossed over onto the left, so that its palmar surface would be directly superposed on that of its fellow were it not for a slight dislocation at the distal end of the humerus, which has carried the rest of the right limb backwards, and so left the left hand exposed. The scapulæ have turned on their axes, but have not shifted sides; and

* This, according to the determination of Mr. Whidborne, is *Ammonites planicosta*.

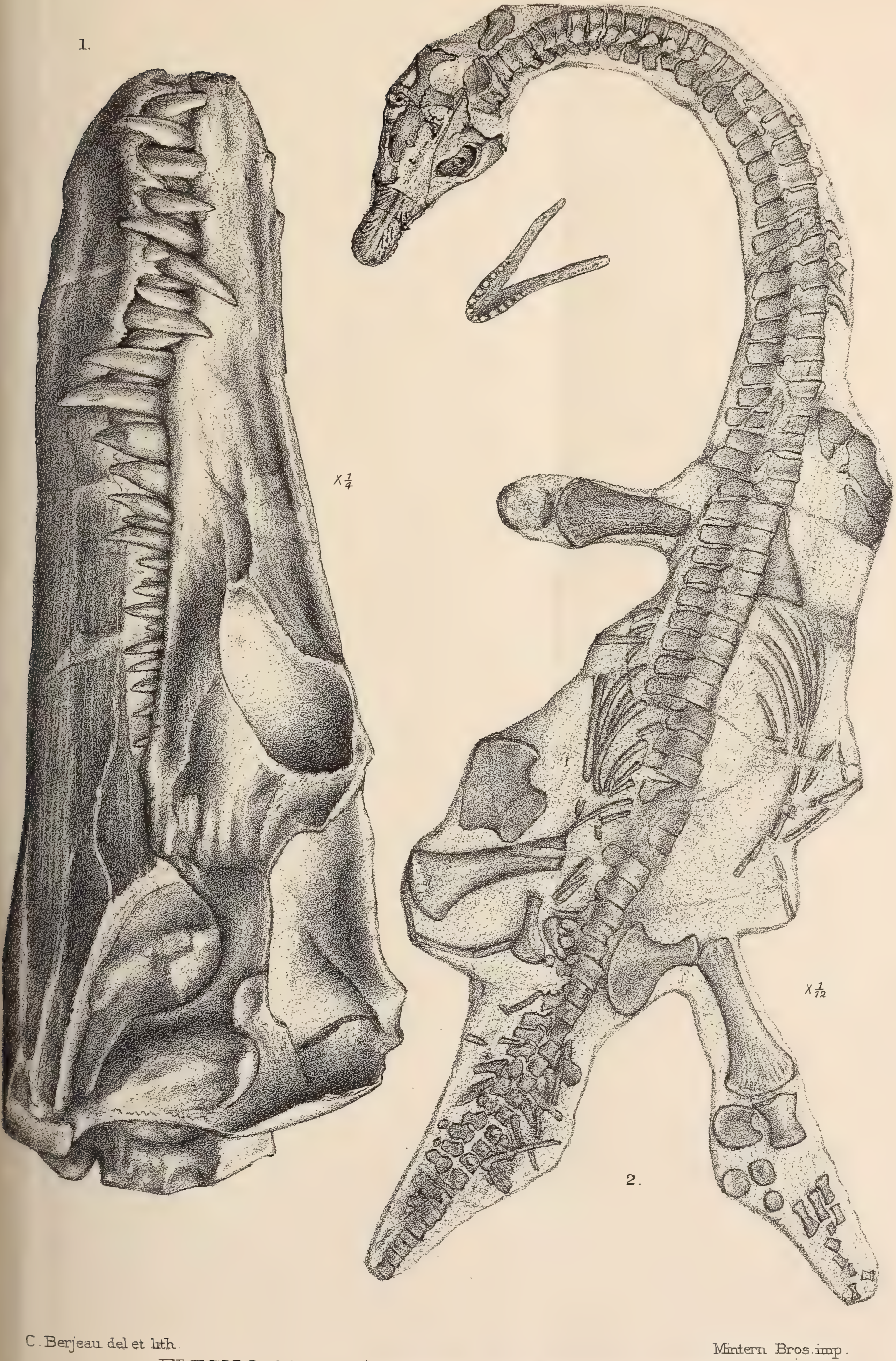




C. Berjeau del. et lith.

PLESIOSAURUS CONYBEARI.

Mintern Bros. imp.



C. Berjeau del et lith.

Mintern Bros. imp.

PLESIOSAURUS CONYBEARI AND BRACHYCEPHALUS

the "furculum," or combined clavicles, is tilted up from right to left.

So far as the appendicular skeleton is concerned, it has approximately the position it would have in an animal lying flat on its back with its limbs extended outwards, except that it has been skewed over as a whole a little to the left, and the right fore limb completely crossed over.

The axial skeleton is similarly disposed as far as the ribs are concerned; but the head and vertebral column have been turned round 90°, and lie on one side, the left. The neck and head are also curved backwards, in the manner so usual with *Plesiosaurus*, and which has been commented on by Professor Huxley as suggestive of death by opisthotonic contraction.

This disposition of the parts of the skeleton may be readily explained by supposing that the animal to which it belonged fell, after death, sideways through some depth of sea-water to an oozy bottom. The body, being broadest laterally, has settled on its back, the hind limbs sprawling outwards. The left shoulder touched the bottom first; and the right fore limb heeling over, fell across the one to the left. The neck and, in this species, the head being broadest dorso-ventrally, settled on one side, the left, and so communicated a twisting strain to the rest of the vertebral column, which, being but slightly attached to the ribs and appendicular skeleton, readily yielded to it, and turned on its side also; thus the whole of the vertebral column came to lie on its broadest face (that is to say, laterally). The twist to the left given by the crossing of the right fore limb, and the subsequent pressure of overlying strata, led to the various other minor dislocations and displacements.

That the specimen is undoubtedly the type of a new species is shown by the following summary of its chief characters:—

1. The length of the skull from the anterior extremity of the lower jaw to the posterior margin of its articulation with the quadrate bone is 19·75 inches, measured along the right side.

2. The number of vertebræ is 66, of which 59 are cervico-dorsal, 2 sacral, and 5 caudal. Of the cervico-dorsal vertebræ 38 appear to be cervical and 21 dorsal.

3. The length of the cervical region is 83 inches (6 feet 11 inches); so that the length of the head is to that of the neck as 24·1 : 100.

4. The length of the cervico-dorsal series is 136 inches (11 feet 4 inches); and the length of the head to this is as 14·6 : 100.

5. The length of the centrum of the anterior cervical vertebræ is equal to the height and greater than the breadth of the articular face. Thus in vertebra xv the measurements are:—Length 2 inches, breadth 1·5 inch, height 2 inches.

6. In the posterior cervical vertebræ the breadth of the articular face is greater than the length or height, but the latter two dimensions remain equal. Thus in vertebra xxxv we find—length 2·7 inches, breadth 3·5 inches, height 2·7 inches.

7. The neural spines increase in size up to the 40th to 44th vertebra, in which they measure 4·75 inches in length.

8. The neural spines are inclined backwards as far as the 55th vertebra; past this up to the 57th they are inclined somewhat forwards; but after this they again incline backwards to the end of the vertebral series.

9. The humerus and femur are nearly equal in length, the femur being slightly the shorter.

For the new species which these characters indicate, I propose the name of *Plesiosaurus Conybeari*, as a tribute to that classic authority who first made the existence and nature of *Plesiosaurus* known to ns. This was sixty years ago; and it is singular that up to this date no one seems to have thought of calling some species of *Plesiosaurus* after the author of the genus.

Plesiosaurus Conybeari agrees closely with *P. Etheridgii* in the relative length of head and neck; but if the length of the head be compared in each with that of the whole cervico-dorsal series, a marked difference is apparent; thus in *P. Etheridgii* the ratio is 12·5 : 100, in *P. Conybeari* 14·6 : 100. *P. Conybearii* further differs from *P. Etheridgii* in absolute size, being nearly twice as long; it also possesses a larger number of cervico-dorsal vertebræ, *P. Etheridgii* having only 53, or 6 less than *P. Conybeari*. In this latter character the new species more nearly agrees with *P. homalospondylus*, each having 38 cervicals, while the latter has 22 and the former 21 dorsal vertebræ; but *P. Conybeari* has a larger head than *P. homalospondylus.* Both have the same length of neck; but *P. homalospondylus* has a longer dorsal series of vertebræ (81 inches in length). The length of its head relatively to that of the neck and cervico-dorsal series is also much less than in *P. Conybeari*, being to the neck as 10·6 : 100, and to the cervico-dorsal series as 5·4 : 100.

Detailed Description.

The Skull (Pl. XXIV. fig. 1).—This, which has been very thoroughly freed from matrix, and is in an excellent state of preservation, presents us with that very exceptional character amongst Plesiosaurs, a good profile. This is due to its having been compressed from side to side, and not, as is more usual, depressed from above downwards. Perhaps this indicates a difference in the original shape of the head. The right side of the skull has slipped a little upwards above the left; and some other displacements have occurred, but nothing like so great as one would have expected if the present greatly compressed head had originally been as broad from side to side as most Plesiosaur heads evidently were.

Posterior Aspect.—In the middle of the back of the skull is a confused mass of bone comprising the axis and atlas vertebræ, under which the *foramen magnum* lies concealed. Inferior to this are the posterior ends (*articulare*) of the rami of the lower jaws, bent towards the middle line; that on the right side is nearly perfect, clearly not needing more than a quarter of an inch to complete it. The *articulare* thins off rapidly behind its articulation with the quadrate, not extending more than 1·5 inch beyond the posterior edge of the condyle.

The quadrate appears to be directly continuous with the squamosal on each side; and the latter bones are prolonged upwards into a process which, viewed from behind, has a somewhat sabre-like outline, with the convexity outwards. Both these suprasquamosal processes are broken at the distal end, so that their junction over the parietal (a characteristic Chameleon feature seen in most Plesiosaurs) is not here observable.

Superior Aspect.—Most posterior is the previously mentioned axis and atlas vertebral mass; then succeed in front the approximated ends of the broken suprasquamosal processes. The parietal comes next, a pent-roof-like bone, 5·75 inches long, compressed for the anterior three quarters of its length into a strong median crest, along which the persistent sagittal suture extends, expanding anteriorly into the *foramen parietale* 0·3 inch wide, in front of which the parietal ends. Behind, the parietal is expanded into a form like the bowl of a spoon, the bowl being supposed turned with the convexity upwards.

The next bones in front are the frontals, longitudinally ridged in the middle, smooth at the sides, and separated by a median suture, which is slightly more open in the middle of its length than at the ends *. A splintery suture joins the frontals to the nasals, which are short longitudinally striated bones, not by any means clearly defined in front from the posterior prolongations of the præmaxillæ. The præmaxillæ, 9 or 10 inches long, are separated for their whole length by a simple suture; posteriorly they are smooth, or only faintly wrinkled, but in front much roughened, probably for attachment of integument.

From the parietals a process is given off on each side of the *foramen parietale*, and continues backwards as far as the middle of the lateral margin of the bone; in uncrushed skulls this process is a plate of bone standing out nearly at right angles to the body of the parietal; its parallelism in this case must be due to compression.

Lateral Aspect.—On the left side the upper jaw is 14·3 inches long; and the anterior 4·3 inches is furnished by the præmaxilla; this bone joins the maxilla along a line which runs obliquely upwards and backwards, to end just above the anterior nares. The maxilla is an irregularly triangular bone. Its base (10″ long) furnishes the margin of the upper jaw; its anterior side bounds the præmaxilla; its posterior side, just behind the apex, furnishes the lower anterior boundary to the external nostril, and further down the lower anterior margin of the orbit (being excluded from the upper part of it by the lacrymal and prefrontal bones, here badly defined); still further downwards and backwards it meets the jugal, by which it is excluded from the posterior half of the lower bonndary of the orbit; and along and beneath this bone it extends to its

* This appears to indicate a fossa corresponding to that on the frontal suture of the Lizard's skull, interpreted by Professor Parker as "the scarcely-closed anterior fontanelle' of *Clarias*."—Phil. Trans. clxx., 1879, p. 598.

termination, which takes place a considerable distance (over an inch) behind the orbit. This is a marked character in several of the Lacertilia, particularly the Agamidæ. The maxilla bears teeth at least up to within 1·8 inch of its termination.

The jugal is bounded below by the maxilla; in front it forms the posterior lower corner of the orbit; above it joins the postorbital (postfrontal), which bounds the upper posterior corner of the orbit; and behind it unites with the squamosal by a splintery suture, which is 1·4 inch long, and runs almost at right angles to the length of each bone. The jugal is convex outwards in front, and depressed behind; in the depression a vertical row of three oval pits (nutritive foramina) separated by intervening smooth ridges is situated. At the ends of the pits, which are elongated antero-posteriorly, striæ appear on the surface of the bone, and are continued forwards, diverging at the same time, over the otherwise smooth anterior convexity. The external form and surface-markings thus described give to the jugal such a characteristic appearance that it is easily identified by them alone.

The squamosal is a large and important bone, of which the general form and relations are not quite so clearly defined as could be wished. Its characteristic anterior or zygomatic process, however, is well displayed; it is a thin bar of bone 1 inch broad, about $2\frac{1}{2}$ inches long, and $\frac{1}{5}$ inch thick, finely striated longitudinally, the striæ sweeping somewhat obliquely forwards from above downwards.

The postorbital continues backwards from the jugal over the upper edge of the zygoma for a distance of 0·8 inch. These three bones, jugal, postorbital, and squamosal, clearly meet in a T-shaped suture; and thus Professor Huxley is undoubtedly correct in asserting that, " contrary to what is usually stated, the postfrontal appears . . . . . . to articulate with a bone, the homologue of the squamosal of the Crocodile" (Quart. Journ. Geol. Soc. vol. xiv. p. 293).

A slight extension downwards of the lower margin of the anterior end of the squamosal bar, rendering its inferior outline curved concavely, while that above is rectilinear, brings it within half an inch of the posterior end of the maxilla. From that part of the jugal which is exposed between the squamosal and the maxilla no bony bar is produced towards the quadrate; nor is there the slightest evidence of one having ever existed, so far as this skull is concerned. I feel persuaded that an inferior bony temporal arcade has never been present, and that, if a quadrato-jugal occurs at all, it must be as what we have called the anterior process of the squamosal, while for such a view I see no evidence.

The quadrate is clearly enough identified at its articulation with the lower jaw; but on tracing it towards the squamosal it is impossible to say where it ends or the squamosal begins. The relations of the two bones are quite obscure; so that one cannot even tell in this specimen whether what we have already termed the suprasquamosal processes are the property of the bones to which we have assigned them, or whether they came off from the quadrate. They appear in other skulls, however, as continuations of the squamosals, though apparently divided from them by suture. Owen calls them "supramastoids;" and they may correspond to Parker's "second supratemporals," though, as they lie exterior to the squamosals and not beneath them, our term "suprasquamosal" is perhaps best retained.

The articular end of the quadrate lies much below the general level of the upper jaw (over an inch). This is a character not found in Agamidæ or most Lacertilia; but it occurs in *Iguana* and the Chameleons.

The Lower Jaw.—This, which has the usual reptilian composition, is 20·35 inches long from end to end; posterior to the symphysis its surface is smoothly striated by longitudinal thread-like ridges, the external expression of its fibrous structure; in front, past the posterior end of the symphysis the surface is much roughened, and along the alveolar margin finely wrinkled *. The length of the symphysis is 3·35 inches; the height of the jaw from the top of the coronary to the lower margin of the ramus is 3 inches.

In the following Table are given the more important measurements of the skull:—

	inches.
Anterior extremity of præmaxilla to posterior margin of parietal	18·0
„ „ anterior margin of orbit	10·0
„ „ posterior margin of orbit	13·0
„ „ „ left nostril	8·2
„ „ „ right nostril	9·2
„ „ foramen parietale	13·0
Vertical height of orbit, left	3·2
Vertical height of orbit, right	2·1
Highest point of parietal to lower margin of lower jaw, left	7·5
Highest point of parietal to lower margin of lower jaw, right	6·3
Anterior end of dentary to posterior margin of articulation with quadrate	19·75
„ „ posterior end of articulare	21·0

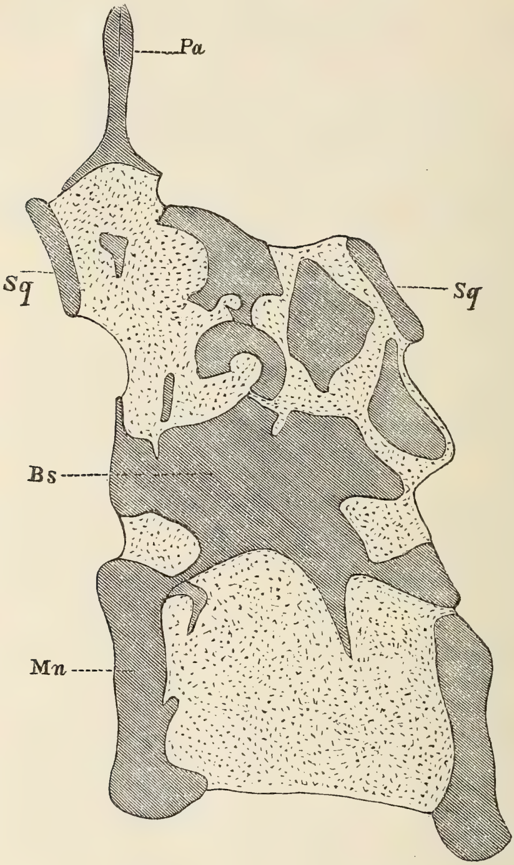
Section across the Skull.—The skull has been broken across in several places, so as to afford a view of its internal structure; but very little is clearly displayed, except in the most posterior fracture, which traverses the supratemporal fossæ (fig. 1, p. 446).

A large and originally bilaterally symmetrical mass of bone is seen in the middle of the section above the lower jaw; the greater part of it consists probably of the basisphenoid; it is channelled in the middle line above by a deep narrow groove, through which a line can be drawn to the middle point of the inferior concave margin opposite, dividing it into nearly symmetrical halves; the right moiety, having apparently suffered but slightly from compression, is better fitted for study than the left, which is much crushed together. The right half is divided by a deep lateral excavation into an upper and a lower portion: the latter, descending outwards and downwards, soon bifurcates; and the upper of the two processes so produced, after diminishing to a narrow neck, widens suddenly into a triangular

* The wrinkled appearance here referred to is very similar to that exhibited by parts of the integument described on page 466.

area, the transverse section of a bone which is continued backwards on the side of the skull to terminate on the inner side of the lower end of the quadrate. In all probability this bone is the pterygoid, or

Fig. 1.—*Transverse Section through the Skull in the Region of the Supratemporal Fossæ.* (Scale $\frac{2}{3}$.)



at all events a part of it; and the narrow neck from which it extends may be partially furnished by the basipterygoid process; but there is no evidence of the existence of a joint between it and the pterygoid. The lower process of the bifurcation may also be a part of the pterygoid; if not, I do not know what nature to suggest for it.

On the left side the pterygoid is crushed up against the basisphenoid, almost obliterating the space which separates them on the right; and the descending process below it is thrust and broken against the lower jaw.

On each side of the section above the basisphenoid the thin bar of bone which proceeds from the squamosal is seen, and at the summit the parietals with their median crest and persistent suture. The other bones appear to be undeterminable; some of them are probably parts of the periotic mass.

Dentition.—A fine series of teeth is well displayed on the left side of the head. They are slender, conical, slightly recurved, and finely striated from the apex for a considerable distance downwards, *i. e.* over the crown. They vary greatly in size, the largest being those in the neighbourhood of the maxillo-premaxillary suture; an inch or so behind this they begin to diminish in size, and beneath the orbit have less than one half the average length of those in front, while behind it they dwindle to mere pointed tubercles.

The largest tooth present is one in the right upper jaw, behind the maxillo-premaxillary suture; it is 2·45 inches long, the distal 1·5 inch, or crown, finely striated, its diameter at the point where the striæ begin being 0·6 inch. A smaller but more perfect tooth, the largest on the left side, measures 1·95 inches long; 1·35 inch is striated; and the diameter at the commencement of striation is 0·5 inch.

Those teeth which still remain exposed to view are distributed as follows:—on the left side in the præmaxilla 5, in the maxilla 15, in the lower jaw 13; on the right side in the præmaxilla 3, in the maxilla 11, in the lower jaw 8. The number of teeth in the left præmaxilla and maxilla make the nearest approximation to the numbers originally present.

The Vertebral Column.—There is a continuous series of 66 vertebræ, of which 38 are cervical, 21 dorsal, 2 sacral, and 5 caudal. The caudal series is evidently incomplete, a considerable number of vertebræ being missing from the distal end.

Cervical Vertebræ.—The first and second, as already mentioned, form a confused mass adherent to the back of the skull, but from the third onwards all are clearly defined and can be easily examined. III. The centrum of the third is 1·12 inch long* (a.p.), 0·75 broad (l.l.), and 1·4 high (d.v.), the breadth and height being measured along the articular face. It is much compressed in the middle, the edges of the articular ends projecting greatly, as though the more yielding cancellous interior had given way under heavy pressure, such as that of overlying strata; this feature is markedly present as far as the thirteenth cervical vertebra. The neuro-central suture is a nearly straight or slightly tricurvate line, with the central convexity downwards. A tricurvate ridge, with the central convexity upwards, runs along the whole length of the centrum between the articular edges or rims, at a level 0·4 inch below the neuro-central suture; it defines the upper edge of the nearly oval costal pit, which is 0·9 inch long, 0·45 inch broad (d.v.), and obscurely divided into two by a faint median longitudinal ridge or closed furrow. The rib has been displaced downwards; and its ovate-lanceolate posterior

* (a.p.) antero-posterior, (l.l.) from side to side, (d.v.) dorso-ventral.

prolongation extends with a downward direction as far back as the posterior edge of the centrum to which it belongs.

Near the articular ends the centrum is roughened by a few small irregularly scattered tubercles, which become larger and more numerous in succeeding vertebræ down to the twenty-fifth. The neural spine has been broken away; so that the total height of the vertebra cannot be determined. The line between the zygapophyses is 1·9 inch from the base, and 0·9 inch from the neuro-central suture.

VII. The seventh vertebra has a total height of 2·95 inches; the centrum is 1·375 inch long and 1·5 high. The well-marked neuro-central suture is 1·1 inch from the base. The tubercles near the articular ends have become larger and more numerous. The rib is distinctly hatchet-shaped, and consists of a blade-like upper part and a lower handle-like horizontal process; a deep incision separates the handle from the blade in front, and the front end of the handle does not reach the anterior edge of the centrum by about an inch. The posterior margin of the blade slopes gradually down, and curves gradually into the handle, the posterior prolongation of which extends a short distance beyond the posterior edge of the centrum, from which the rib proceeds.

The anterior zygapophysis is, as in the other anterior cervical vertebræ, turned inwards and upwards; below the line of the zygapophyses the neural arch is ridged in a direction crossing obliquely from the anterior edge of the anterior zygapophysial facet downwards to the posterior edge of the neuro-central suture, the ridges being most marked near their origin and termination. The distance from the anterior to the posterior zygapophysis is 2·3 inches. From the line of the zygapophyses to the base of the centrum is 2·0 inches, to the top of the spine 1·35 inch.

The neural spine has somewhat the outline of a Phrygian cap seen in profile; it has a gentle convex slope backwards in front, and a short sigmoid curve behind; it rises from the middle of the length of its centrum, and hangs over the anterior quarter of the centrum next behind. It is smooth below, but roughened towards the distal end.

The vertebræ increase in size and change in the relative size of their parts as they pass backwards: down to the fifteenth (XV), probably to the twenty-second (XXII), the articular face of the centrum is an ellipse, with the major axis vertical (d.v.); at the twenty-third (XXIII) the diameters are about equal, and continue so to about the twenty-fifth (XXV), beyond which the horizontal diameter (l.l.) becomes the larger, and continues to increase over the vertical down to and beyond the end of the cervical series. The neuro-central suture becomes more sharply inflected in the middle, so that in the fifteenth (XV) the middle curve of the tricurvate line becomes transformed into a right angle. The zygapophysial facets acquire by degrees an entirely horizontal position; they seem to have done so in the fifteenth vertebra.

The neural spines increase more rapidly in size than the centra, and considerably change their form; at the eighteenth (XVIII) the spine is broader at the distal end than in the preceding vertebræ. The anterior margin is short and straight, sloping backwards; the upper margin curved, rising obliquely backwards; the posterior margin is sigmoid, convex backwards above, and concave below, nearly vertical. In the thirty-second (xxxii) the outline is much simpler: both anterior and posterior margins are straight, not quite parallel with each other, since they are further apart below than above; the upper margin is an elliptical curve, through which the anterior and posterior margins pass into each other. The base of the anterior part of the spine between the anterior zygapophyses is much compressed; it broadens out immediately behind the origin of the anterior zygapophyses, and also over the posterior zygapophyses. The costal pits increase in size; but neither they nor the ribs show much sign of other change down to the twenty-sixth (xxvi) vertebra, when, however, preparations for change become evident.

In the twenty-sixth, the rib being displaced allows the costal pits to be seen; they are now quite separate oval depressions, 0·95 inch long and 0·9 inch distant from the anterior edge of the centrum, with which they are connected by a ridge which continues the anterior margin of each forwards.

In the twenty-seventh (xxvii) all trace of rugosity has disappeared from the surface of the centrum, and it is now quite smooth; this continues to be the case throughout the rest of the vertebral column. The neuro-central suture is marked by a swelling ridge, particularly prominent in the central part of its course.

In the twenty-ninth (xxix) the thickening of the lower end of the neural arch becomes more marked, and the margin of the costal pits is somewhat elevated.

In the thirtieth (xxx) faint signs appear of a ridge proceeding from the swollen end of the neural arch to the upper margin of the costal pit; in the thirty-first (xxxi) this and the ridge connecting the anterior margin of the costal pit with the anterior edge of the centrum have both become more marked. In the thirty-second and thirty-third (xxxii and xxxiii) the costal pits begin to rise higher on the centrum, and become more posterior; the upper edge of the pit swells into a marked ridge, and is connected by the previously mentioned ridge, which (now become very prominent) ascends from it to the swollen end of the neural arch.

In the thirty-fourth (xxxiv) the lower costal pit has almost disappeared, and the upper and anterior margins of the remaining pit are swollen into a strong crescentic ridge, which is joined in the middle by the ridge descending from the neuro-central suture.

In the thirty-fifth (xxxv) the thickened lower end of the neural arch and the ridge arising from the anterior margin of the costal pit form together a single vertically descending median ridge, which extends more than halfway down the side of the centrum. That part of the ridge contributed by the neural arch is more swollen than the other, and curves forwards as it descends, joining at an obtuse angle the part contributed by the centrum, which is sigmoid in outline; the general form of the united ridge is much like that of a bracket (}), the middle point of the bracket standing for the point of junction of the two constituent ridges.

In the thirty-sixth (XXXVI) the lower end of the neural arch is still more swollen, and has retreated further up the centrum; it more abruptly joins the costal ridge, which has become almost straight, and more prominent; it extends down the middle of the centrum to within 0·65 inch of an oval nutritive foramen, which lies on one side of the concealed middle line of the base of the centrum.

(XXXVII) An abrupt change in the character of the costal ridge takes place in the thirty-seventh vertebra; it has become greatly enlarged, to form a simple transverse process, which, curving downwards and backwards from the neural arch, ends in an oval facet, looking obliquely backwards and downwards; the lower edge of the facet rests upon the centrum, the pedicel of the transverse process having as yet only an upper and not an inferior margin. The rib is no longer hatchet-shaped, but of the ordinary half-hoop form; it is nearly cylindrical down to 1·3 inch from the transverse process, and then expands laterally so as to become somewhat triangular in section; the line along which this change takes place is marked by a strong ridge, oblique to the axis of the rib. A transverse fracture across the front of this vertebra and the overhanging posterior zygapophyses of the preceding vertebra shows that the zygapophysial facets are not horizontal (as one might have conjectured), but much inclined, the posterior looking outwards and downwards, and the anterior inwards and upwards.

(XXXVIII) The base of the transverse process of this vertebra extends a little more than halfway down the centrum; the facet is borne on a distinct pedicel, and looks a little less backwards than that of the preceding vertebra. This I take to be the last cervical vertebra, the transverse process of the next vertebra appearing to arise wholly from the neural arch. I use the word "appearing" definitely, since, in the absence of any well-defined neuro-central suture, it is difficult to say certainly what the exact constitution of the transverse process is. It is clear, however, that the process in this vertebra extends a little below the dorsal half of the centrum; and this is presumptive evidence* that it is cervical; while in the next vertebra it does not, but is wholly confined to the dorsal half, and thus should be the first dorsal. Moreover, owing to a difference in the colour of the substance of the centrum and that of the neural arch, the latter being black and the former brown, in this region of the vertebral column, it is possible to detect in the transverse process of the thirty-eighth vertebra bone contributed by the centrum; in the transverse process of the thirty-ninth no certain indication of bone so contributed is to be found. The possession of hatchet-shaped ribs was at one time included by Professor Huxley in the definition of a cervical vertebra; if this should be regarded as an essential character, then the vertebræ thirty-seven and thirty-eight would

* "There is reason to believe that the neurapophyses do not extend upon the bodies of the cervical vertebræ beyond their dorsal half."—HUXLEY, on *Plesiosaurus Etheridgii*, Quart. Journ. Geol. Soc. vol. xiv. p. 282 (footnote).

be excluded from the cervical series, and there would be only thirty-six cervical vertebræ. If it were desirable to make a natural grouping of the vertebræ of this skeleton without reference to those of other species, one would not hesitate to draw the line between cervical and dorsal at the end of the thirty-sixth vertebra; for all down to the thirty-sixth are without transverse processes, but possess hatchet-shaped ribs, while past the thirty-sixth the hatchet-shaped rib disappears and unmistakable transverse processes correspondingly arise. As, however, it is convenient to adhere as closely as possible to existing conventions, in order to facilitate the comparison of species, I have been governed in my determination of the last cervical by the fact that a part of the transverse process borne by it does clearly seem to be contributed by the centrum as far back as the thirty-eighth vertebra; and thus I have included as cervical two vertebræ which would certainly seem more in place in the dorsal series. Professor Seeley's plan of calling those vertebræ in which the transverse process is passing from the centrum onto the neural arch "pectoral" has much to recommend it, and might fairly be applied to the vertebræ thirty-seven and thirty-eight. Indeed there is just a shade of doubt in my mind whether vertebra thirty-nine should not also be called pectoral; for its transverse process appears to have a little brown bone like that of the centrum at its base, and the rib it bears is bifurcate near the head and short, while the succeeding vertebræ bear ribs with a simple proximal termination only.

The determination of the position of the last cervical vertebra is not only important as giving us the number of vertebræ in the neck, but also because it furnishes us with a necessary datum for the measurement of the length of the neck, and hence for ascertaining that important character, the ratio of the length of the head to that of the neck, or, as we may briefly term it, the cervico-cephalic index. Fortunately, in the case of the species under consideration the neck is so long that one or two vertebræ more or less can make very little difference to the value of this index, the thirty-seventh and thirty-eighth vertebræ measuring together not more than five inches. The thirty-eight cervical vertebræ measure 83·25 inches, or 6 feet 11 inches; and the cervico-cephalic index is 24·1. A Table is here appended, giving the dimensions of the cervical vertebræ, so far as they are ascertainable: it will be seen that the constancy in length which Prof. Owen * regards as characteristic of the cervical vertebra of the Enaliosauria, and only exceptionally absent in *Pliosaurus*, has no real existence, and also that no single vertrebra can well be taken as typical of the remainder. Hence the importance of such a Table as this as a help in the specific identification of separate vertebræ will be apparent. It may be worth while to call attention to the abrupt manner in which some of the changes in dimensions occur, as for instance in the length of the centrum in passing from the twenty-second to the twenty-third vertebra; and again, to the abnormal

* Report Brit. Assoc. 1841. Report on British Fossil Reptiles, p. 63.

variations which occasionally appear, as, for instance, in the twenty-eighth vertebra, which is longer not only than its predecessor, but also than its successor; the same is also the case in the thirty-sixth vertebra: the difference is too large to be explained as an error of measurement, and can scarcely be the result of mechanical compression; it seems rather to be concomitant with that wide departure from the ordinary Reptilian type which the Plesiosaurian neck presents.

Table of Measurements of Cervical Vertebræ.

Number of the vertebra	Centrum.			Total height.	Zygapophysis to base.	Zygapophysis to end of spine.	Zygapophysis to Zygapophysis.	Neuro-central suture to base.	Neuro-central suture to costal pit.	Number of vertebra.
	Length. (a.p.)	Breadth. (l.l.)	Height. (d.v.)							
1.										
2.										
3.	1·12	0·75	1·4	...	1·9	...	...	1·2	0·4	3.
4.	1·25	...	1·4	...	1·9	...	2·1	1·1	0·4	
5.	1·25	...	1·4	...	2·0	1·35	...	1·1	0·4	5.
6.	1·375	...	1·4	2·9	2·0	...	2·3	1·1	0·5	
7.	1·375	...	1·5	2·95	2·0	...	2·3	1·1	0·5	
8.	1·375	...	1·5	2·95	2·0	1·45	2·3	1·1	0·5	
9.	1·375	...	1·5	3·2	2·0	...	2·3	1·1	0·5	
10.	1·7	...	1·5	...	2·25	...	2·45	1·05	0·5	10.
11.	1·7	...	1·7	...	2·3	...	2·45	1·2	0·5	
12.	1·7	1·4	1·7	...	2·45	...	...	1·2	0·5	
13.	1·8	1·45	1·75	...	2·45	...	...	1·4	0·5	
14.	1·9	1·4	1·9	...	2·4	1·9	...	1·4	0·5	
15.	2·0	1·5	2·0	4·0	2·6	2·1	2·75	1·5	0·6	15.
16.	2·1	...	2·1	4·6	2·6	2·2	2·85	1·55	0·7	
17.	2·2	...	2·1	4·8	2·6	2·45	3·05	1·55	0·7	
18.	2·2	...	2·2	5·1	2·8	2·45	3·05	1·5	0·7	
19.	2·2	..	2·2	5·2	2·8	2·65	3·2	1·7	0·7	
20.	2·2	...	2·2	5·4	2·8	2·8	3·2	1·7	0·8	20.
21.	2·3	...	2·15	5·4	2·8	2·8	3·4	1·45	0·65	
22.	2·2	...	2·2	5·6	2·8	2·8	3·4	1·5	0·55	
23.	2·5	2·3	2·2	...	3·0	2·9	...	1·8	0·75	
24.	2·55	2·4	2·2	5·85	3·1	3·0	3·5	2·0	0·7	
25.	2·5	..	...	6·6	3·4	3·3	3·7	...	0·7	25.
26.	2·5	...	2·25	6·4	3·5	3·1	3·55			
27.	2·65	...	2·35	6·55	3·55	3·45	3·7	2·2	0·8	
28.	2·75	2·45	2·5	6·8	3·5	3·65	...	2·0	0·8	
29.	2·6	...	2·6	6·8	3·5	3·85	3·7	2·3	0·75	
30.	2·6	...	2·65	6·8	3·6	3·6	3·7	2·3	0·7	30.
31.	2·65	...	...	7·1	3·6	3·9	3·9	2·6	0·65	
32.	2·5	...	...	7·1	3·7	3·98	3·9	2·4	0·5	
33.	2·625	...	...	7·3	3·7	4·0	...	2·6	0·5	
34.	2·6	3·3	2·7	7·5	3·8	4·25	...	2·7	0·2	
35.	2·69	3·5	2·7	7·7	3·8	4·4	...	2·8	...	35.
36.	2·75	3·5	2·75	...	3·8	...	...	2·8		
37.	2·6	..	...	...	3·55					
38.	2·6	3·625	2·725	...	...	...	...	...	...	38.

Dorsal Series. (Plate XXIII. fig. 2.)

The dorsal vertebræ are well exposed in a fine and complete series on the underside of the specimen. They have the same general character as the last two cervicals—the centrum being smooth, not tuberculated, its height (d.v.) and length (a.p.) being about equal, and both shorter than the breadth (l.l.). The maximum dimensions of the centrum appear to be attained in the fortieth vertebra, in which the length and height are each 2·8 inches, and the breadth 4·8 inches; its total height, however, is only 7·6 inches, being less than that of the forty-third vertebra, which is 8·2 inches high; behind the fortieth the centra decrease in size, and a little more rapidly in breadth than in the other dimensions. The transverse processes rise upon the vertebræ from the thirty-ninth (XXXIX) to the forty-second and forty-third (XLII and XLIII) beyond which they spring from the neural arch along the zygapophysial line; they maintain this position down to the fifty-sixth (LVI), past which they begin to descend and also change in character. At first, as in the fortieth vertebra (XL) or second dorsal, the pedicel of the transverse process projects outwards at right angles to the vertical plane given by the flat side of the neural spine; passing backwards this angle is much diminished, so that in the forty-fourth (XLIV) vertebra it is only 65°; behind this it begins to increase again, and at length becomes 90° at the fifty-fifth (LV) vertebra, or seventeenth dorsal.

The length of the transverse process increases slowly down to the forty-seventh (XLVII), in which it is 4·3 inches long; behind this it slowly shortens and becomes 1·5 inch at the fifty-eighth vertebra.

The dorso-ventral diameter of the base of the transverse process is at first, as in the fortieth vertebra, 2·1 inches; but it rapidly diminishes, so that at the forty-third it has become 1·2 inch; past the forty-third it remains pretty constant as far as the fifty-sixth vertebra. At the fifty-sixth important changes commence; the transverse process loses its straight boldly projecting form and droops, as it were, into a curve, assuming the character of the last cervical transverse process. In the fifty-eighth vertebra the facet is inclined downwards and backwards; but its form cannot be fully made out, as its lower half is concealed by the head of its rib.

The neural spines are parallel-sided, and truncated above by a straight or very gently curved distal margin. They attain their greatest length and breadth in the fortieth to forty-third vertebræ, past which they diminish in size slowly. In the early part of the dorsal region the spines are inclined backwards at a slight angle; thus in the fortieth to forty-second vertebræ the axis of the spine makes with the zygapophysial line an angle of 64°, *i.e.* it slopes backwards 36° from the vertical; posteriorly the backward inclination diminishes and the spine becomes at length vertical; this is the case at the fifty-fifth vertebra; still more posteriorly the inclination becomes reversed and the spine slopes forwards; thus in the fifty-seventh vertebra it makes an angle of 93° with the zygapophysial line, *i. e.* it is inclined forwards at an angle of 3° from the vertical; at the sixtieth (LX) vertebra (1st sacral) the spine has resumed its backward inclination.

The Ribs.

The early dorsal ribs for about two inches from the proximal end are almost straight; they then somewhat rapidly bend into a curve, which is steeper near its origin and straighter towards the end. At the fifty-first vertebra the curvature of the rib has become less, in the fifty-third much less; and at the fifty-fourth the rib is straight. The longest ribs are those of the forty-seventh to the fiftieth vertebræ; behind the fifty-second they rapidly shorten, those of the fifty-sixth being only 5·4 inches, and of the fifty-ninth 2·7 inches long.

For a short distance from the head the ribs are roughened with irregular longitudinal ridges, which are most marked in the anterior, and absent in the last few posterior dorsal ribs. All possess simple proximal ends, except the first dorsal, which gives off a short process just below the head.

Sacral Vertebræ.

The two vertebræ regarded as sacral are the sixtieth and sixty-first (LX and LXI). In them the transverse process has become very short, little more than a raised facet, the surface of which, however, is larger than that of the preceding transverse process of the last dorsal. It obviously consists of two nearly equal parts—an upper contributed by the neural arch, the articular face of which is a plane surface, meeting along a horizontal line at an obtuse angle the similar plane surface of the inferior moiety contributed by the centrum. The ribs are short (1·9 inch long) and slightly expanded at the distal ends. The neural spines are inclined backwards, making in the sixtieth an angle of 80°, and in the sixty-first of 78°.

Caudal Vertebræ.

If the determination of the sacral vertebræ be correct, then there are five caudal vertebræ, the dimensions of which are given in the appended Table (page 455) of measurements for all vertebræ past the last cervical. The spines are broken away from them all except the first, in which it is suddenly inclined backwards at a much greater angle than that of the last sacral. The zygapophyses are nearly vertical.

The transverse processes are now represented merely by pits with raised margins, only the upper part of which is furnished by the swollen end of the neural arch. The ribs remain short; but that of the first is longer than that of the last sacral.

Table of Measurements of Postcervical Vertebræ.

No. of vertebra.	Centrum. Length.	Centrum. Breadth.	Centrum. Height.	Total height.	Zygap. to base.	Zygap. to end of spine.	Zygap. to zygap.	Breadth of spine.	Length of anterior margin of spine.	Length of spine along middle line.	Inclination of spine to line of zygap.	Inclination of transverse process with spine.	Length of rib.	Length of transverse process.	Height of base of trans. process (d.v. diam.).	Height of facet of trans. process (d.v. diam.).	Bread of fac of tran verse process.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	°	°	in.	in.	in.	in.	in.
39.	2·6	3·5	2·8	...	4·2												
40.	2·8	4·1	2·8	7·6	3·1	4·75	...	2·4	3·9	4·625	64	90	......	1·5	2·1	1·0	1·0
41.	2·76	......	......	7·7	...	4·75	...	2·1	4·0	4·5	64	75	......	1·5	1·8	1·2	1·0
42.	2·76	......	......	8·0	3·5	4·75	...	2·5	4·25	4·5	64	76	......	1·4	1·3	1·25	1·15
43.	2·76	......	......	8·2	3·5	4·75	...	2·1	4·2	4·3	72	68	......	1·6	1·2	1·1	1·25
44.	......	3·2	2·85	8·0	3·5	4·75	...	......	4·0	4·0	72	65	......	1·7	1·2	......	1·25
45.	2·65	3·15	2·85	8·1	...	4·4	...	2·1	3·65	3·8	72	66·5	......	1·9	1·25	1·3	1·35
46.	2·65	......	......	...	...	......	...	2·1	3·65	4·0	72	66	......	2·2	1·15	1·2	1·35
47.	2·65	3·2	2·6	7·8	...	......	...	2·1	3·6	3·8	72	72	......	2·3	1·2	1·2	1·5
48.	2·65	......	......	...	...	......	...	......	......	......	...	...	17	2·2	1·15	1·15	1·5
49.	2·4	......	......	...	...	......	...	1·9	......	......	78	72	17·75	2·2	1·15	1·15	1·4
50.	2·33	......	......	...	...	......	...	1·9	......	......	80	76	17·6	2·1	......	1·0	1·4
51.	2·33	......	......	7·3	...	......	...	2·05	......	......	83	76	......	2·0	......	0·9	1·25
52.	2·33	......	......	7·3	3·8	......	...	2·05	......	......	86	78	......	1·9	1·15	0·9	1·25
53.	2·33	......	......	...	...	......	...	2·05	......	......	86	85	......	1·9	1·15	0·9	1·2
54.	2·33	......	......	...	...	......	...	......	......	......	...	84	......	1·8	......	0·85	1·05
55.	......	......	......	...	3·6	......	...	1·85	......	......	90	90	5·4	1·6	......	0·85	1·1
56.	2·3	2·9	2·3	6·7	...	......	...	......	......	......	...	...	4·6	1·7	......	0·9	0·8
57.	2·3	......	......	...	...	......	...	......	......	......	93	...	4·0	1·6	......	0·8	0·8
58.	......	......	......	...	...	......	...	......	......	......	...	...	3·5	1·5	......	......	0·9
59.	......	......	......	...	...	......	...	......	......	......	...	...	2·7	1·1	......	......	0·9
60.	2·1	......	......	...	...	......	...	......	......	......	80	...	1·9	1·4	......	1·5	1·0
61.	2·0	......	......	...	...	......	...	......	......	......	78	...	......	...	......	1·5	1·15
62.	......	2·6	2·2	...	...	......	...	......	......	......	52	...	......	...	......	1·3	1·05
63.	2·0	2·6	2·25	...	...	......	...	......	......	......	52	...	......	...	......	1·3	0·8
64.	......	2·5	2·175	...	...	......	...	......	......	......	...	...	......	...	......	1·1	0·9
65.	2·0	2·5	......	...	3·8	......	3·8										
66.	......	2·0															

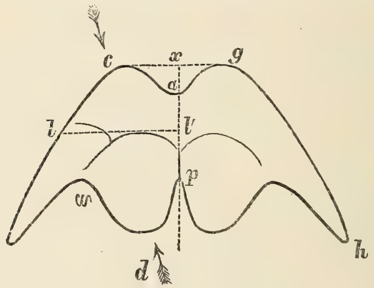
Pectoral Arch.

The bones of the pectoral arch are all present, though somewhat displaced from their original position. They consist of the furculum, coracoids, and scapulæ.

The Furculum.

This (fig. 2) is a large bilaterally symmetrical plate of bone, convex ventrally from side to side, with two long thin tapering lateral wings, one on each side, directed backwards and slightly dorsally; a tri-curvate anterior margin, the central curve being a large semicircular excavation, which passes into a curve convex forwards on each side; and a gently curved posterior margin convex backwards, with a narrow deep incision running forwards along the median line, or axis of symmetry. The lateral curve of the anterior margin passes insensibly into the front margin of the lateral wing; the posterior margin meets the posterior margin of the wing in a rounded angle.

Fig. 2.—*Diagram of the Furculum.* (Scale $\frac{1}{8}$.)

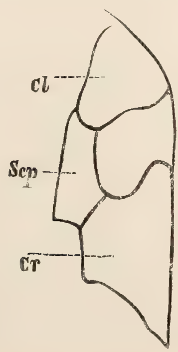


If one draws a line from the central point of the curve, which we have just called a "rounded angle," parallel approximately to the anterior margin of the bone, we shall divide the body into two parts, the anterior of which is much thicker than the posterior, being at least 1 inch across; it is of somewhat dense or close texture superficially, but loose and open in the middle: the posterior part is very thin, a mere lamella of bone. The anterior part may be distinguished as the "body" proper of the bone; the posterior, which is divided into two by its median longitudinal fissure, is a pair of "lapels;" and thus with the "wings" we have five distinct regions present, but of true sutures I cannot find a trace; the whole appears to be a single piece of bone, though having regard to the great difficulty there often is in discovering sutures which do really exist in fossilized bones, I should not wish to be thought too positive on this point.

The bilateral symmetry of the bone and its median longitudinal notches, point to its connate nature; its position in front of the coracoids, between the prescapular processes of the scapulæ, points to its clavicular origin: I regard it therefore as representing a pair of fused clavicles, which repeating the behaviour of the coracoids, have expanded into extensive plates over the ventral surface. An interclavicular element appears to be absent; there is no room for it, except in the position conjecturally assigned to it by Professor Seeley, who has suggested that it forms the anterior middle part of the bone. This, however, is a position which it occupies in no other known reptile, as it is always more or less posterior instead of anterior to the clavicles. Since writing the first part of this paragraph I have been able to devote a few minutes to an examination (which I wish could have been less hasty) of a loose specimen of Plesiosaurian furculum, preserved in the British Museum, the same bone, I fancy, that is figured as a sternum in Hawkins's monograph. It certainly shows traces of sutures, and is marked on the surface by striæ, which appear to indicate a median and lateral elements. It has a suggestive resemblance to the clavicles and interclavicle of a Chelonian like, say, *Trionyx*. But it differs considerably in form and appearance from the furculum of our species; so that it is doubtful how far it can be used as a guide. Very possibly the furcula of different Plesiosaurs may differ in composition, as they do in Birds, an interclavicle being sometimes present and sometimes absent.

There is another difficulty attending the interpretation of the furculum; and that lies in its position beneath the prescapular ends of the scapulæ, which overlap its posterior lapels. In all recent reptiles the clavicles are superficial to the scapulæ, while here just the reverse is the case. This is proved by more than one well-preserved specimen in the British Museum, showing the scapular processes abutting on the body of the furculum, and also by Lord Enniskillen's specimen of *P. macrocephalus*, which affords us a dorsal view of the left clavicle overlapping the dorsal surface of the scapula (fig. 3).

Fig. 3.—*Diagram showing the left side of the Pectoral Arch of* P. macrocephalus, *seen from behind*. (The wing of the furculum conceals the termination of the scapula.)



This anomalous position I altogether fail to explain: if the lapels could be shown to be precoracoids, all would be clear; but this view is not without difficulties.

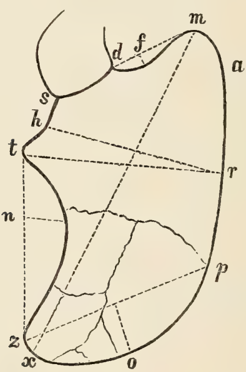
The dimensions of the bone are given below:—

	inches.
Antero-posterior diameter in the median line (fig. 2, *a p*)	3·65
Maximum antero-posterior diameter (ib. *c d*)	6·4
Antero-posterior diameter from *a* to *w*......	5·25
Breadth (twice the line *l l′*)	8·6
Length of wing (*g h*)......................	8·4
Width of anterior excavation (*c g*)	2·55
Depth of anterior excavation (*a x*)	1·05
Depth of posterior incision	2·1

The Coracoids.

The coracoids (fig. 4) have the usual Plesiosaurian form, presenting together a close and almost ludicrous resemblance to the front of a short jacket.

Fig. 4.—*Diagram of the Right Coracoid.* (Scale $\frac{1}{8}$.)



The inner margins of the bones meet for half their length in a straight median harmonia, diverging gently outwards from each end of it. The outer margin has a simple concave sweep backwards behind the articulation for the humerus; the anterior margin projects in an elliptical curve in front, the outer edge of the curve sinking into a curve backwards, which joins the almost straight margin of the scapular articulation. The bone is thickest where it furnishes the articulations for the scapula and humerus. Thence it continues with only slightly diminished thickness along a ridge or keel, which extends transversely to its inner margin. This ridge, which rises from the ventral surface of the bone, and as shown by a transverse fracture, is scarcely, if at all, marked on the dorsal surface, is defined in front by a curved line, which commences near the anterior end of the scapular articulation, curves backwards to the middle of its course, and then forwards till it ends against the inner margin of the bone; posteriorly it is defined by a line very slightly curved, convex backwards, which commences from the hinder end of the humeral articulation and passes very slightly backwards, also to end against the inner margin. From this ridge the bone thins rapidly away in front and behind, more rapidly in front, till it ends in a thin edge.

The posterior region of the right coracoid is traversed by several lines of fracture, on one side of which the surface of the bone remains higher than on the other, and thus forms little cliffs. A broken surface, dividing the bone across, reveals its internal structure, and shows between its dense outer layers a more cancellous open tissue in the middle; not only so, but in some places the middle of the bone is occupied by a layer of calcite; and this is thicker on that side of a fracture where the surface is higher, and thinner on that side where it is lower. This calcitic layer is probably due to the replacement of cartilage; and it is thinner where the bone is thinner on the side of a crack, because the cartilage had there been squeezed together by pressure of overlying strata.

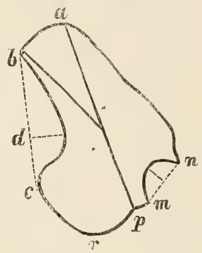
The measurements of the right coracoid are given below:—

	inches.
Maximum length (fig. 4, *m x*)............	17·375
Length of harmonia (ib. *a p*)............	10·5
Breadth (ib. *t r*).....................	8·6
Breadth along median ridge (ib. *h r*).....	8·0
Distance from anterior end of coracoid to posterior edge of glenoid cavity (ib. *m t*)..	10·0
Length of chord of anterior concave margin of coracoid (ib. *m d*)...............	2·75
Height of arc of anterior concave margin of coracoid (ib. *f*).....................	0·375
Length of articulation for the scapula (ib. *d s*)	3·3
Length of articulation for the humerus (ib. *s t*)	3·2
Thickness at articulation for the humerus..	1·6
Length of chord of posterior and outer lateral curve (ib. *t z*).....................	8·3
Height of arc of posterior and outer lateral curve (ib. *n*).........................	2·3
Length of chord of posterior convex margin (ib. *z p*)...........................	7·5
Height of arc of posterior convex margin (ib. *o*).............................	3·3
Thickness of median ridge where broken in middle of its course (left coracoid)......	0·91
Thickness of anterior region of coracoid....	0·25
Thickness of posterior region of coracoid ..	0·6

The Scapula.

This (fig. 5) consists of a ventral plate, from the outer lateral margin of which a lateral plate arises and ascends towards the dorsal surface, its plane being inclined to that of the ventral plate at an angle of about 90°. The ventral plate is longer than broad, thicker behind than in front, truncated by a slightly convex edge anteriorly, bounded by a widely open V-shaped margin behind, the inner stroke ($c\,r$) of the "V" representing its articulation with the coracoid, the outer stroke ($r\,p$) its share in the glenoid cavity for the humerus. The

Fig. 5.—*Diagram of Right Scapula.* (Drawn reversed, scale $\frac{1}{8}$.)



inner lateral margin is concave, the outer straight; and from along its whole length the lateral plate arises. The latter is like a long scalene triangle in shape, the apex lying in front, the longest side being that common to it and the ventral plate, and the next longest its outer edge; the base of the triangle is not a straight line, but a deep concave curve arising from the anterior edge of the glenoid cavity, passing forwards and upwards and then backwards to the end of the outer edge. The lateral plate, when complete, is not bounded by a simple outer or upper margin, as here described, but is prolonged upwards along its posterior third into a thin narrow ascending process: this process is broken off both scapulæ in our specimen; and the posterior third of the outer edge of the lateral plate is consequently a surface of fracture.

Dimensions of the Scapula.

	inches.
Length of outer edge of ventral plate (fig. 5, $a\,p$)	8·1
Breadth at distal end (ib. $a\,b$)	2·4
Length of chord of concave inner margin (ib. $b\,c$)	5·05
Height of arc of concave inner margin (ib. d)	1·2
Length of articular surface for coracoid (ib. $c\,r$)	2·2
Length of articular surface for humerus (ib. $r\,p$)	1·9
Length of chord of posterior concavity of ascending plate (ib. $m\,n$)	2·1
Height of arc of posterior concavity of ascending plate (ib. $m\,n$)	1·0

Restoration of the Pectoral Girdle. (Plate XXIII. fig. 3.)

The displaced bones retain their original outline so perfectly, that if it were possible to move them relatively to each other into their original positions the pectoral girdle would be well restored; as, however, the stony matrix in which they are imbedded renders this impossible, I have made careful outline drawings of the several bones, and then cut these out and fitted them together, being guided in doing so by a direct study of the bones themselves. The result is given in the diagram (Plate XXIII. fig. 3).

The furculum lies in front in the middle line; and the prescapular processes of the scapulæ abut each on its own side upon the outer posterior border of the furcular body proper, covering its wings, which appear to lie in the angle between the ascending scapula and its prescapular process. The lapels face the anterior projecting convexities of the coracoids without touching them. There is thus produced a single continuous foramen, bounded laterally by the concave inner borders of the scapulæ, anteriorly by the furcular lapels, and posteriorly by the anterior margin of the coracoids; it is wide from side to side, narrow from before backwards, and roughly resembles in form two brackets joined face to face, thus :— 

In the fact that the foramen is not subdivided into two by the overlapping of the furcular lapels by the coracoids, this species differs from some other species of Plesiosaurs; a corresponding difference is displayed in the pelvic arch, the foramen between the pubes and ischia, likewise double-bracket-shaped, being continuous from side to side, and not divided into two, as happens in most other Plesiosaurs.

The Humerus.

The right humerus is carried over to the left side, and lies with its flat posterior surface uppermost (Pl. XXIII. fig. 1). For the proximal third of its length it is a thick cylindrical bone, with an elliptical transverse section, the major axis being twice the length of the minor axis (4 inches and 2 inches respectively); it then widens out into a broad plate-like distal portion for the remaining two thirds of its length. The ulnar margin is almost straight, only slightly convex; the radial more curved and concave. It is covered superficially with irregular longitudinal ridges, more abundant on the radial than the ulnar side, which is almost smooth, and most marked near the ends of the bone; at the anterior end they become broken up into irregular tubercles.

The left humerus is similar to the right; but its surface is smoother, and its proximal half less elliptical or more circular in section; it begins to widen a little past the middle of its length, widens and flattens then rapidly, becoming very thin ($\frac{1}{4}$ inch) towards its distal edge. The more rapid expansion of the left than of the right humerus is almost certainly due to compression, though without the latter bone for comparison we should have nothing to indicate this; hence a possibility to be borne in mind in making specific determinations of isolated bones.

The Radius.

The right radius is a straight, almost parallel-sided bone, elliptical in transverse section, truncated by slightly convex ends; it has a simpler outline than is usual in Plesiosaurs. The left radius, which has suffered more from compression, has more of the usual Plesiosaurian outlines: its outer edge is gently concave, its ulnar margin tricurvate, the middle curve being concave inwards; and its once cartilaginous articular surfaces have been squeezed beyond the edge of the flat surface of the bone. It is much ridged longitudinally, the ridges diverging a little from the middle towards the ends.

Representing the length of the humerus by 100, that of the radius will be 37; and this number may be called the humero-radial index. Its value for other species is found in the table on page 477. For *P. rostratus* it will be seen to be almost the same as for *P. Conybeari.*

Dimensions of Humeri, Radii, Ulnæ, and Femora.

	Diameter of head.		Diameter at middle of length.		Diameter of distal end.			Length	
	Ra. Ul.	A. P.	Ra. Ul.	A. P.	Ra. Ul.		A. P.	from end to end.	from capitular ridge to end.
					chord.	arc.			
Humerus:—									
Right......	3·5	2·9	3·9	2·0	6·7	8·2	1·2 (?)	14·8	15 A. 14·25 P.
Left	(?) 3·6	3·2	3·9	2·0	...	·55	...	14·8	14·8 P.
Femur:—									
Right......	3·5	3·6	3·4	2·0	6·7	...	1·2	14·25	12·75 M. 13·5 A.
Left	3·5	3·8	3·7	1·6	...	...	1·2	14·37	13·37
Radius:—									
Right......	...	...	3·6	...	3·5	3·75	0·7	5·45	...
Left	3·9	0·8	3·15	0·55	3·5	3·5	0·55	5·0	4·75
Ulna:—									
Right......	2·8	...	3·9	...	4·85	6·5	0·7	5·5	...
Left	2.8	0·7	3·7	...	4·7	6·0	...	5·6	...

Ra. Ul. means from radial to ulnar margin; A. P. means from anterior to posterior margin; Chord means measured along chord of curve; Arc means measured along curve itself. In the last column A., M., P. mean measured to anterior, median, and posterior edge of distal margin respectively.

The Ulna.

The right ulna, like the right radius, retains more of its original form than the corresponding bone on the left; for although its distal two thirds are much flattened, its proximal third still presents its original thickness.

This uncompressed portion has a smoother surface than the other, which is distinctly ridged; the entirely compressed left ulna is ridged all over; and this leads one to suggest that the ridges on fossil bones may in some cases have been subsequently produced by mechanical pressure. Let the soft cancellous interior of a bone be crushed together, and the denser outer layers, in adapting themselves to a more circumscribed area under pressure, may possibly become finely wrinkled, and thus give rise to a spurious appearance of ridges.

The Carpus.

The carpus, 7·25 inches in breadth, consists of two rows of three bones each, which diminish in size from the ulnare to the radiale. They are polygonal bones, with the dimensions given in the table below. In the left manus the distal row of carpal bones alone bears the fingers, the radiale carrying one, the intermedium and ulnare two each. In the right manus the ulnare of the proximal row appears to bear one finger, the ulnare of the distal row two, the distal intermedium one (but it contributes a small facet for the adjoining digit of the ulnare), and the distal radiale, as in the left manus, one.

	Length.			Breadth.		
	Radial.	Inter-medium.	Ulnare.	Radial.	Inter-medium.	Ulnare.
Proximal series...	1·6	2·3	2·65	2·15	2·5	2·75
Distal series	1·8	1·4	2·9	2·1	1·8	2·1

The Manus.

The hand, where broadest, is 8·5 inches across. It consists of five digits; the first, with five phalanges, is incomplete in both hands; the rest are complete in the left manus—the second, third, and fourth having nine, and the fifth eight phalanges. The third and fourth fingers are the longest. The phalanges have the usual form, a compressed hour-glass outline,—except the most distal, which is triangular, and apparently equivalent to the proximal half of one of the other phalanges, the distal half being suppressed: it has much the appearance of an ungual phalanx, and may very well have borne a nail.

The measurements of the phalanges are averages of those of the right and left manus, and in the case of the breadth, of the distal and proximal ends of each phalanx.

Phalanges.

	Length.					Breadth.				
	I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
i..........	1·9	2·5	3·0	3·0	3·1	1·25	1·15	1·35	1·35	1·75
ii..........	1·8	2·5	2·5	2·6	2·45	...	1·35	1·4	1·25	1·1
iii..........	2·9	2·1	2·1	2·5	2·4	1·2	1·45	1·4	1·5	1·3
iv..........	1·8	1·75	1·95	1·95	2·0	...	...	1·25	1·25	1·0
v..........	1·75	2·05	1.7	1·65	1·65	1·15	1·15	1.1	0·9	0·8
vi..........	?	1·3	1·65	1·4	1·4	...	·95	1·0	0·8	0·7
vii..........	?	1·3	1·2	1·2	1·15		0·72	0·72	0·7	0·55
viii..........		1·0	0·8	1·0	0·45		0·55	0·45	0·45	0·35
ix..........		0·8	0·7	0·6	...		0·44	0·3	0·3	...
Total length of fingers	?	17	18	18·25	16·8					

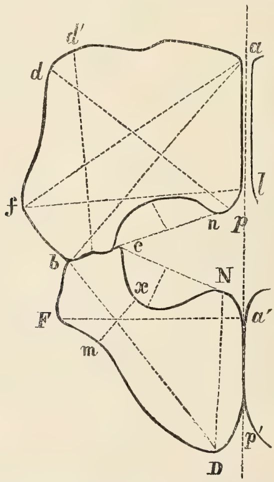
The Pelvis.

A restoration of the pelvic girdle, obtained in the same way as that of the pectoral arch, is given on Pl. XXIII. fig. 4.

The Pubes (fig. 6).

These are more or less quadrangular plates, which meet each other in a straight median symphysis along nearly their whole length. The anterior margin is an undulating curve, with a general direction at right angles to the symphysial margin. The posterior margin, at first a little convex, becomes concave for half its length outwards from the symphysis, then almost straight and parallel to the ante-

Fig. 6.—*Diagram of the Right Pubis and Ischium.* (Scale $\frac{1}{8}$.)



rior margin as it articulates with the ischium; finally it curves forwards and outwards, to contribute its share to the acetabulum, and joins the outer margin, which has a slope obliquely outwards as it passes backwards from the anterior margin.

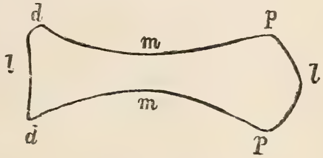
The Ischium (fig. 6).

This "shoulder-of-mutton" shaped bone meets its fellow for about half its length in the median symphysis. The ∽-shaped anterior margins of the two ischia meet to form together a bracket-like outline (—⌄—); the similarly shaped posterior margins of the pubes do the same; and the brackets facing each other give rise to a foramen, which is continuous from the pubic ischial smyphysis on one side to that on the other. In this character the pelvis resembles that of *Murænosaurus*, Seeley, Q. J. G. S. vol. xxx. p. 206.

The Ilium (fig. 7).

The ilium has the usual Plesiosaurian form, a central shaft with expanded ends, compressed in different planes, which are inclined at about a right angle with each other.

Fig. 7.—*Diagram of Right Ilium.* (Scale $\frac{1}{8}$.)



Measurements of Pelvic Bones.

Pubis.

	inches.
Length of symphysis (fig. 6, *a p*)	5·5
Breadth of bone from symphysis, and along a line at right angles to it, to anterior edge of acetabulum (ib. *f l*)	8·5
Maximum antero-posterior diameter, drawn from *d'*	8·1
Length of diagonal from inner anterior angle to anterior edge of acetabulum (*a f*)	10·3
" " from inner anterior angle to posterior edge of its share of acetabulum (*a b*)	10·3
" " from outer antero-posterior to inner posterior angle (*d p*)	9·0
" articular surface for acetabulum (*f b*)	2·9
" " " for ischium (*b c*)	2·3
" chord of posterior concavity (*c* N)	3·9
Height of arc " "	1·25

Ischium.

Length of symphysis (*a' p'*, fig. 6)	5·5 to 6·0
Breadth along a line at right angles to symphysis to posterior edge of acetabulum (*a'* F)	7·8
Length from outer edge of its articulation with the pubis to its posterior angle (*b* D)	10.1
Length from anterior inner angle to posterior angle (N D)	7·725
Minimum diameter across "neck" (*m x*)	2·4
Length of symphysial margin for pubis (*b c*)	2·4
" acetabular margin (*b* F)	2·5
" chord of anterior concavity (*c* N)	3·85
Height of arc of anterior concavity (*x*)	1·8

Ilium.

	Right ilium. inches.	Left ilium. inches.
Length (*l l*, fig. 7)	6·9	7·2
Breadth of proximal end (*p p*)	2·4 (?)	2·85
„ distal (*d d*)	2·3	1·9
Minimum diameter of shaft (*m m*)	...	1·0

Note.—The proximal end of the right ilium is slightly broken, and its distal end compressed, probably by subsequent pressure.

The Femora.

These bones, which are smaller than the humeri, have the articular head well defined by a sharp surrounding ridge; the articular surface itself is deeply pitted and tuberous, indicating the previous existence of a thick covering of cartilage which has since disappeared.

The cylindrical proximal end is slightly constricted below the capitular ridge before it begins to expand. The dorsal and ventral margins are almost straight lines, or only slightly concave curves, which diverge gently from the thick proximal to the broad and flattened distal end. The distal end is truncated by a simple gently convex curve.

The surface of the bone is roughened beneath the head, and strongly ridged at the distal end with longitudinal lines, which diverge in conformity with the curves of the lateral margins of the bone.

The Integuments.

Remains of what appears to be some dermal structure have been stated by previous writers to occur in connexion with *Ichthyosaurus*; and Charles Moore in particular has well described a thin layer having a wrinkled surface, which invests a large number of the Ichthyosaurs in the collection of the Bath Museum; but no one, so far as I know, has made mention of any similar investment in the case of *Plesiosaurus*. Great interest therefore attaches to the presence of a thin brownish film, with characteristic surface-markings, which coats a considerable portion of the specimen under consideration.

It is best displayed on the surface between the fortieth and sixtieth vertebræ, covering the bodies, transverse processes, and neural spines of the vertebræ, the ribs, and the surface of stony matrix intervening between them. It also extends in a band over an inch broad, along the distal ends of the neural spines, at a little distance from them as now exposed.

This band, which seems to restore the dorsal outline, ends in the pelvic region, where it covers the head of the right femur, and imbeds a small oblong bone, the smooth shining surface of which is raised into three parallel longitudinal ridges; other fragments of similar bone are indicated near the same spot. Their presence can scarcely be accidental; and they may possibly be dermal plates. That they are not found elsewhere would simply point to the restricted distribution of dermal scutes in the species, they having originally been present in the pelvic region and nowhere else. The thin film, however, has nothing of the nature of scales and scutes, so far as we can see; it was a continuous membrane, not a collection of separate individual structures. It can easily be detached from the underlying surface, owing, it would seem, to the presence of a thin whitish layer, apparently calcite, which is more strongly adherent to the film than to the surface beneath.

The surface of this film is variously marked; but all the different markings may be described as essentially of the nature of wrinkles. In the film of the dorsal band they have the appearance of fine regular rounded ridges, giving the surface a resemblance in some degree to "corded silk;" elsewhere, as over the bases of some of the neural spines, the ridges lose to a great extent their straightness and regularity, take a tortuous course, though generally with one prevailing direction, and are more apparently mere wrinkles; but over the greater part of its extent an additional feature presents itself in the form of long, fine, parallel grooves, bordered by fine ridge-like margins, and looking as though they had been scored by a fine needle: they vary in distance from each other; but the best-marked are about $\frac{1}{20}$ inch apart. They maintain one general direction from before backwards on the bodies of the vertebræ, the exposed outer sides of the ribs, and on the stone between them, from the forty-second to the fiftieth vertebra. Between the grooves minute wrinkles are abundant, mostly undulating, sometimes straight, not always confined to the space between two grooves, but sometimes crossing them without changing their course; they are inclined at all angles to the grooves, but are chiefly transverse to them.

What the precise nature of this film may be is by no means clear. From its distribution one might infer that it originally formed a part of the integumentary investment. It closely resembles in character the structure which has been regarded by Mr. Moore as forming a part of the integument of *Ichthyosaurus*, and which this acute observer has compared to the wrinkled surface of the skin of the Porpoise *. The resemblance between this surface, as seen in our museum-specimens, and that of the investing film in *Plesiosaurus* is, indeed, great; and if such a skin were capable of fossilization, one might fairly allow that *Plesiosaurus* had been invested with it. It is very certain that the film in our fossil specimen was of a yielding flexible nature, or it could not have so neatly covered the exterior of the ribs and adapted itself to the ends of the transverse processes and the angles between the neural spines and the vertebral bodies as it has done.

* Som. Archæol. & Nat. Hist. Soc. Proc. 186–566, p. 179.

Classification.

The pectoral arch in its essential characters is truly Plesiosaurian, though it differs from most Plesiosaurs in the fact, if it be a fact, that the coracoids do not extend in front so as to overlap the "lapels" of the furculum.

To make plain its relations to other members of the genus *Plesiosaurus,* I have constructed the following Table, in the last four columns of which the distribution of the vertebræ amongst the various regions of the spine is given for each species.

In comparing the length of the head with that of the neck (or rather of the cervical series of vertebræ) I have uniformly made use of the proportion :—

$$\frac{\text{length of head}}{\text{length of neck}} = \frac{I}{100}.$$

The value found for I may be conveniently called the cervico-cephalic index. This index is given, for each species in which it has been determined, in the first column of the Table.

In the second column I have similarly compared the length of the head and the dorsal series of vertebræ (excluding sacral vertebræ). The indices of this column are dorso-cephalic.

The total length has not been made use of in comparison, since it is seldom possible certainly to obtain it, and variations in the length of the caudal region are of secondary value ; but in the third column values are given for the length of the head compared with the cervico-dorsal series (exclusive of sacral vertebræ). To the cervico-dorsal cephalic index great value may be attached, since it can frequently be obtained and is independent of any error in the method or the practice of determining the position of the last cervical vertebra. It is true it may be affected by a mistaken determination of the first sacral vertebra ; the sacral vertebræ, however, are more easily determined than the last cervical ; and an error with regard to them will not cause a deficiency or excess of more than one or two vertebræ to the cervico-dorsal series, while I am convinced much larger errors have been made with reference to the number of vertebræ in the cervical series ; and, finally, in comparatively so great a length as that of the cervico-dorsal series one or two vertebræ more or less will have but a trifling effect on the value of the index obtained from them. Another index of some interest is the cervico-dorsal, obtained by referring the length of the neck to that of the trunk taken as 100.

The values now given for the various indices will certainly in many cases need revision, since the measurements on which they are founded are often extremely unsatisfactory. Sometimes they are unreliable or erroneous, sometimes vague (as when the length of the "trunk" is given without stating whether the sacral vertebræ are included or not, or when the length of one part is given in fractions of another*; and sometimes, finally, they are not comparable, as when in one place the length of the skull is given (as it too frequently is) as the length of the lower jaw, while in another it is taken as the length between the end of the snout and the basioccipital.

On reference to the Table it will be seen that *P. Conybeari* has the same number of cervical vertebræ as *P. homalospondylus*, but one less dorsal: its head, however, is much larger than that of the latter species; and hence there is a great difference in their respective cephalic indexes. In proportion of head to neck it agrees exactly with *P. Etheridgii*, but differs widely in the number of cervical vertebræ. It has also two dorsal vertebræ fewer; and its dorsal and cervico-dorsal cephalic indexes are distinctly different. Its cervico-dorsal index approaches nearest to that of *P. Hawkinsii*, in which species this index attains its maximum value.

Plesiosaurus.	Cephalic indexes.			Number of vertebræ.				Cervico-dorsal index.	Humero-radial index.
	Cervico-cephalic.	Dorso-cephalic.	Cervico-dorsal cephalic.	Cerv.	Dors.	Sac.	Cau.		
Zetlandicus	87·6	58·3	33·9	...	...	...	...	72·2	
rostratus............	63·9	51·1	28·4	24	24	2	34	92·3	37·4
propinquus	60·0	55·5	28·85	25	23	2	34	92·6	45·8
Cramptoni.........	55·5	41·6	24·0	27	30	2	32	75·0	28·5
megacephalus ...	53·3	49·3	26·5	30	26	2	34	92·6	33·5
macrocephalus ...	51·2	65·6	28·8	29	20	2		128·0	31·0
brachycephalus ...	35·3	40·3	18·8	31	24	2	21	114·0	33·3
longirostris	33·8	29·7	15·8	33	25		32	87·5	34·5
Hawkinsii	30·0	46·9	18·3	31	23	2		156·2	34·7
Etheridgii	24·3	26·0	12·5	30	23	2	34	106·0	
Conybeari	24·1	37·4	14·6	38	21	2	5+	153·0	37·0
dolichodeirus......	17·7	23·6	10·1	41	21	2	30+	133·3	42·9
macropterus	12·8	17·0	7·3	39	24	1?	28	132·0	50·0
homalospondylus	10·6	11·1	5·4	38	22	2		105·0	46·0

There is a fine specimen of *Plesiosaurus* in the British Museum, with the MS. name *P. laticeps*, Owen, which bears a close resemblance to *P. Conybeari*. Its pectoral and pelvic girdles are well exposed on their ventral surface, and are strikingly similar in general form and arrangement to those parts in *P. Conybeari*; the dimensions of their component bones also show a general agreement, as will be seen from the following table. In each the humerus is longer than the femur; but these bones are each an inch shorter in *P. laticeps* than in *P. Conybeari*.

* Thus, in his Monograph on Liassic Reptiles, Professor Owen says of *P. rostratus* that the skull is $\frac{3}{4}$ the length of the neck. Now the skull is 1 foot 11 inches long; and thus the length of the neck should be 2 feet 6 inches 8 lines. But he also says that the length of the neck is rather less than $\frac{1}{3}$ the length of the spinal column; as the latter is 9 feet 9 inches long, the neck should be "rather less" than 3 feet 3 inches long. Whereabouts between these two quantities is the exact length? And would it not seem to have been easier to directly state it? Unfortunately the instance here given does not stand alone.

Table of Measurements of corresponding Parts in P. laticeps, *Owen,* M.S., *and* P. Conybeari.

	P. laticeps. inches.	*P. Conybeari.* inches.
Furculum, length (a.p. dia.)	6·0	6·4
Coracoid, length (maximum)	17·0	17·375
„ breadth	8·0	8·0
Pubis, length of symphysial margin (a.p. dia.)	6·5	5·5
„ „ parallel to outer margin (a.p. dia.)	8·0	8·1
„ „ oblique diameter from inner anterior to postero-exterior angle	10·0	9·0
Ischium, length (max. obl. dia.)	9·0	10·1
Humerus, length	13·5	14·5
Femur, length	12·5	13·5
Neck, from first cervical vertebra to anterior edge of furculum	56·0	78·0
Trunk, from anterior edge of furculum to posterior edge of pubis	48·0	53·0
Number of cervical vertebræ from first to anterior edge of furculum	27	38
Length of posterior cervical vertebra	2·25	2·5
Length of dorsal vertebra	2·375	2·65

The anterior end of the head is broken off and missing in *P. laticeps*; so that the cephalic indexes cannot be determined.

The regions of its vertebral column cannot be clearly defined, since the pectoral and pelvic girdles conceal to some extent the vertebræ beneath them. There is no great difference in the length of the dorsal region of the two species; as shown in the Table, in *P. Conybeari* it is 5 inches longer than in *P. laticeps*, a difference which may be accounted for by supposing the furcula of the former to be displaced a little forwards.

The widest departure is seen in the neck, its length being much less and the number of its vertebræ much fewer in *P. laticeps*; but there is an artificial look about the neck of this specimen which leads me to conjecture that some of the cervical vertebræ may be missing, so that, if those which remain were arranged as they were first found, several considerable lacunæ would appear between them.

The lengths of the centra of the cervical and dorsal vertebræ make a close approximation in the two species, *P. laticeps* in this, as in several other characters being a little the smaller. The anterior cervical vertebræ of *P. laticeps* are rugose or tubercular in the same fashion as those of *P. Conybeari.*

Finally, both species come from the same "gisement," the Lower Lias of Charmouth.

If my conjecture with regard to the identity of the two species should prove correct (and it will require a closer examination of Owen's species than I have been able to give it to decide this), then of course the name "*laticeps*" will have to be suppressed. It occurs in print in the 'Geological Magazine,' vol. iv. p. 144, but without accompanying diagnosis or specific description.

One other character of *P. Conybeari* alone remains for comparison; and that is the relative dimensions of its vertebral centra. If we find the proportion of the breadth and height of a centrum to its length taken as 100, we shall obtain its latitudinal and altitudinal indices. These are given in the following Table for the cervical vertebræ of a number of species. To make their comparison of value, corresponding vertebræ should be selected for each species; and for this tables like that on p. 452 would have to be constructed and discussed. As it is, I have had to make the best use I could of the material ready to hand in published papers, and to trust to the chance of different describers having given measurements of an average cervical vertebra. Most of the indices in the table have been derived from the thirteenth to the fifteenth vertebræ, and probably are sufficiently comparable.

Plesiosaurus	Latitudinal index.	Altitudinal index.	Number of vertebra.
Conybeari	70	100	XV.
homalospondylus	92	72	XIII & XIV.
rugosus	107	100	
cœlospondylus	110	106	XV.
plicatus	112	84	XV.
macrourus	112	100	Middle.
infraplanus	113	101	Average of middle and basal half of neck.
dolichodeirus	113	94	
arcuatus	116	116	
carinatus	120	98	
sp. from Aust	123	113	
Hawkinsii	125	112	
validus	127	102	
eleutheraxon	127	100	
costatus	134	119	
subtrigonus	140	109	
oxoniensis	140	116	
pachyomus	142	110	
trigonus	150	120	
eleutheraxon	169	100	
rostratus	170	155	XV.

It will be seen that the centrum of the fifteenth vertebra of *P. Conybeari* has a lower latitudinal index than any other known species, while its height remains about the average.

P. homalospondylus, which makes the nearest approach to it, is equally remarkable for its exceptionally low altitudinal index.

The compression which the cervical vertebræ of *P. Conybeari* have undergone may to some extent account for the narrowness of their centra; but it cannot be altogether explained in this way, since it persists in a marked manner down to the twenty-eighth vertebra. Moreover our measurements were taken from the articular ends of the centra; and these show no obvious signs of compression.

The Table shows a general tendency in the long-necked species towards a low latitudinal index, and in short-necked species towards a high one; but the rule is subject to exceptions, and we have not enough instances to reason from. The latitudinal has clearly a greater range of variation than the altitudinal index.

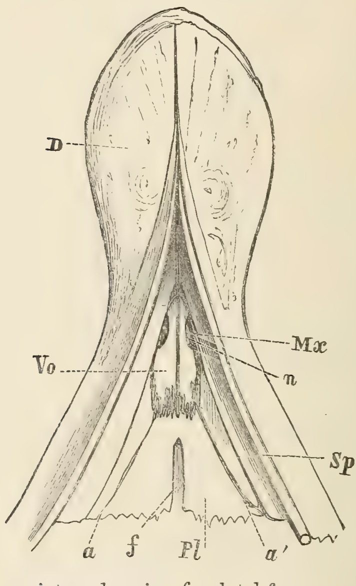
Notes on Plesiosaurus megacephalus, *Stutchbury, and* P. brachycephalus, *Owen.*

The type specimens of these two species are preserved in the Bristol Museum; so that I have had a good opportunity of making a close acquaintance with them, and have succeeded in elucidating some points in their anatomy which were hitherto obscure.

PLESIOSAURUS MEGACEPHALUS.

1. *The Roof of the Mouth.*—The skull of this specimen lies on its dorsal surface, separated from its matrix from the snout to a transverse fracture which traverses it across the orbits. The matrix has been carefully chiselled away from between the rami of the lower jaw, so as to clearly expose the roof of the mouth and the base of the skull for its entire length. The anterior part of the base (fig. 8), which lies in front of the fracture before mentioned, is by a most lucky chance much better-preserved than that behind, and thus affords us an opportunity which has long been desired of ascertaining more exactly the true nature of this part of the skull.

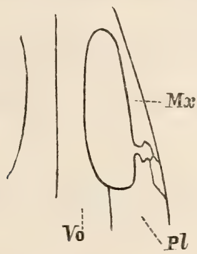
Fig. 8.—*Ventral View of the anterior Part of the Skull of* P. megacephalus. (Scale $\frac{1}{3}$.)



n, internal naris; *f*, palatal foramen.

It presents, about 2 inches behind the end of the mandibular symphysis, two oval foramina (fig. 8, *n*) longer than broad (1·45 inch in length) separated from each other by a bone which extends backwards in the middle line and unites by a splintery suture with the palatines behind. It shows traces of a straight sutural union along its median antero-posterior diameter, and consists, without doubt, of the connate vomers. On their outer margin the foramina are bounded (fig. 9) for the anterior three quarters of their extent by the maxillæ, for the remaining quarter and along their posterior margin by the palatines, and along the inner border (as before mentioned) by the concave outer margin of the conjoined vomers. The vomero-palatine

Fig. 9.—*Diagram showing the left Internal Naris of* P. megacephalus, *bounded by the Maxilla, Vomers, and Palatine.* (Scale ½.)



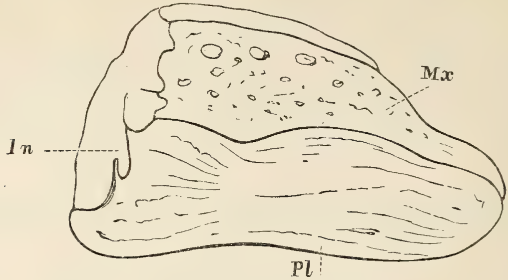
suture has more or less the shape of a W, as exposed on the floor of the skull, the apex of the W being on the median line, and the end of its lateral strokes cutting the inner posterior angles of the foramina.

The palatines extend backwards for some distance as flat, horizontal plates, suturally united in the middle line, and completely roofing over the front of the mouth. Their sutural union is interrupted for a part of its course by an elongated vacant space (fig. 8, *f*) which clearly corresponds to the palatal foramen of many Lizards (e. g. *Iguana*, in which it is well seen).

An oblique linear fissure starting from the middle of the outer stroke of the W of the vomero-palatine suture runs on each side outwards and backwards, to disappear against the matrix bounding the roof of the mouth. These fissures might easily be mistaken for sutures, in which case they would be regarded as indicating the line of junction of the palatines; they are, however, simply fractures which have broken the palatines along a line where they become flanged upwards and outwards to join the maxillæ. The fractures are, indeed, continued through the skull; so that the middle part of it, included between them, can be readily separated from the outer part on each side, and the form of the palatines and their union with the maxillæ clearly exposed (fig. 10).

Another fracture traverses the skull nearly vertically, but oblique to the axis, passing through one of the external nares, and one of the oval foramina, or nares, as we may venture to call them, before mentioned. This fracture shows (fig. 11) a large central chamber, now filled with the Lias limestone; it is bounded above by the

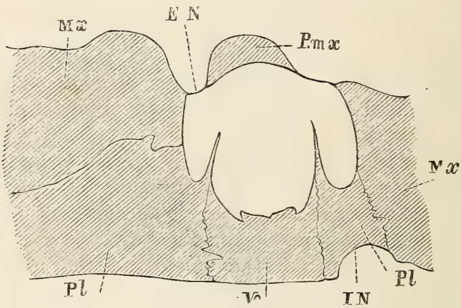
Fig. 10.—*Oblique Fracture through the Skull of* P. megacephalus, *showing the line of union of the maxilla and palatine.* (Scale ½.)



In, Internal nasal passage.

præmaxillæ, below by the vomers and palatines, and on each side by the maxillæ, and also in some parts of its course by the palatines.

Fig. 11.—*Transverse Fracture through the Skull of* P. megacephalus, *crossing the nasal chambers.* (Scale ½.)



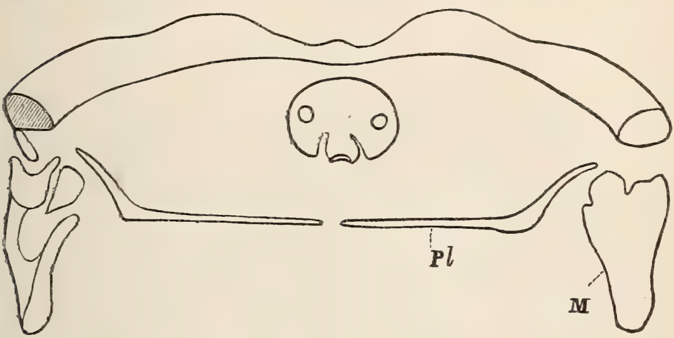
EN, external naris; *IN*, internal naris.

The vomers (fig. 11, *Vo*) form a trough-shaped bone of considerable thickness, flat below but concave above, with a low ridge on each side of the middle line; its sides extend upwards, together with a process from the palatines, as a curved wall for half the height of the central chamber, which is thus divided through its lower half into a middle and two lateral portions. The lateral portions have the appearance of tubes sloping downwards and forwards. On each side of the præmaxillæ the external nares open freely into the central chamber; while the foramina on each side of the vomers communicate with its lateral passages. These passages are bounded externally by the maxillæ, and internally, as well as inferiorly, by the palatines.

The oval foramina appear to represent the internal nares, since they are similarly situated with respect to the surrounding bones as the posterior nares of many Lacertilia; and it is with this order that *Plesiosaurus* stands in the closest connexion.

It must be borne in mind, however, though I doubt whether it is generally known, that the posterior nares by no means occupy a constant position in the Lacertilia; for though they are most usually bounded in the manner above stated, they sometimes shift their position backwards and open at the back of the palatines. In such cases, however, the palatines are produced towards the middle line, each along its outer edge, into an underlying plate, which roofs over the mouth and forms a floor to the nasal passages. A section across the Plesiosaurian skull might be expected, therefore, to give some signs of an inflection of the palatine bones, converting them into incomplete tubes, if such a backward extension of the nasal passage obtained in it. No such signs, however, are to be detected in the specimens under consideration. A diagrammatic sketch of a fracture passing transversely through is given below (fig. 12); it shows plainly the outward and upward bend of the palatines, but not a trace of an infolding.

Fig. 12.—*Transverse Section across the Skull of* P. megacephalus, *showing the palatal plates flanged upwards and outwards towards the Maxillæ, but not inflected to form a nasal passage.*

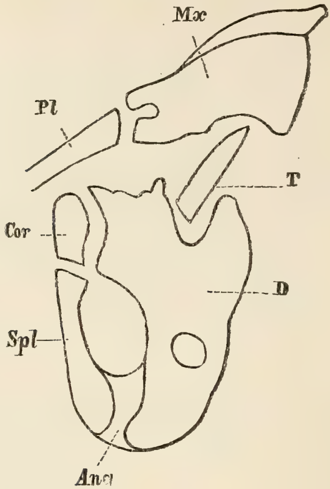


It is a fact too curious to be passed over, however, that the internal are situated in advance of the external nares of this Plesiosaur, the anterior margin of the latter being a trifle under 2·8 inches behind that of the former.

A transverse section through the upper and lower jaws is given in fig. 13: the upward flange of the palatine is seen meeting the maxilla; and the lower jaw has the usual reptilian composition.

2. *Redetermination of the Number and Distribution of the Vertebræ and of the Length of the Regions of the Spinal Column.*—Of cervical vertebræ, twenty-nine are visible up to the anterior edge of the furculum; in all probability one more lies beneath this bone; and the total number may therefore be taken as thirty. In consequence of the concealment of a large part of the spine beneath the pectoral and pelvic girdles, the number of dorsal

Fig. 13.—*Transverse Section through the Jaws of* P. megacephalus. (Scale ½.)



T, tooth.

vertebræ can only be indirectly arrived at. The total length of that part of the vertebral column which lies between the anterior edge of the furculum and the posterior edge of the ischium is 70 inches; from this 2·3 inches must be deducted on account of the concealed last cervical vertebra, and 6·9 inches for three post-dorsal vertebræ supposed to be concealed beneath the ischium, two of them being sacral and one the first caudal. This leaves 60·8 inches (70 − 2·3 − 6·9 = 60·8), which is the length of the dorsal region. Divided by 2·3, the average length of a dorsal vertebra, this gives 26·43, or, neglecting the fraction, 26, which is the number of vertebræ in the dorsal series. These numbers are embodied in the annexed Table (page 477), in which the measurements of a number of specimens of different species are compared together.

Plesiosaurus brachycephalus, Owen. (Plate XXIV. fig. 2.)

This species has not been figured, and has been only partly described. I do not intend here to do more than offer a few observations upon it, and to correct the previously made measurements.

1. *The Skull.*—Although incomplete and broken, the skull is but slightly distorted, and presents several points of interest.

The snout is broken away from the rest of the skull, and shows the under surface perfectly. It is 5 inches long, and does not exhibit the internal nares; so that they must have been situated further back. Its broken surface extends at right angles to its long

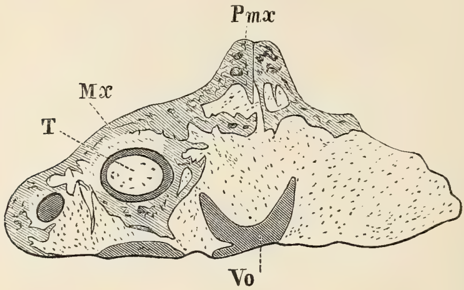
Species.	Total length.	Head.	Neck.	Trunk.	Sa-crum.	Tail.	Fore limb.	Hind limb.	Hu-merus.	Fe-mur.	Ra-dius.	Tibia.	Ulna.	Fibula.	Ma-nus.	Pes.
* megacephalus	195	30	56·3	60·8	4·6	54·5	33+	......	13·7	13·5	4·6	4·5	4·3	4·5		
* Cramptoni	268	40	72	96	......	66	60	......	21	22	6	6·5	6·5	6		
†macrocephalus	59+	10·5	20·5	16	1·5	11+	12.75	13·5	4	4·75	1·25	1·4	1·15	1.3	8	9
‡brachycephalus	129	14·5	41	36	2·5	23	......	......	9	9·75	......	3·25	......	3		
longirostris	170	23·75	70 ?	80	.. ...	50	44	......	14·5	......	5	......	5			
†Hawkinsii	69	7·5	25	16	.. ...	20·5	17	16·5	5·75	5·5	2·0	2·0	1·8	1·8	......	9·5
* Etheridgii	96·8	6·8	28	26·5	2·5	26	......	......	7·2	7·15						
* Conybeari	171	20	83	53·5	4·25	10+	44·5	......	14·8	14·25	5·45	......	5·5	......	23·6	
†dolichodeirus	113	8·5	48	36	......	24	......	......	7	7	3	3	......	......	12	14
macropterus	182	9	70	53	......	48	42·5	46·5	12	11	6	5	......	......	20	25
homalospondylus	198	9	85	81	......	32	44	45	12 13	13 14	5·5	......	......	......	24	24
rostratus	140 ?	23	36	39	......	39	24	28·5	9	9·75	3·3	3·1	3·3	......	13	
propinquus	180	30	50	54	......	52	44	......	12	......	5·5	......	5·5			
†zetlandicus	228	42	52	72	......	74	......	......	20							

The measurements are given in inches.

In those marked * the length of the head is taken from the anterior edge of the præmaxilla to the posterior edge of the quadrate; marked thus, †, it is taken as the length of the lower jaw; thus, ‡, from anterior edge of the præmaxilla to end of parietal.

axis, and since it has been polished reveals very clearly the arrangement of the bones in this region of the skull (fig. 14).

Fig. 14.—*Transverse Section through the Skull of* P. brachycephalus. (Scale $\frac{3}{4}$.)



The upper and backwardly prolonged processes of the præmaxillæ are seen on each side of the middle line above, the maxillæ bearing teeth on each side, the vomers in the middle line below conjoined to form a single trough-shaped bone; a plate of bone forming the roof of the mouth on each side of the vomers is an extension inwards of the maxillæ.

The left orbit is complete and undistorted; it is bounded by the usual bones, the sutures between them being exceptionally plainly shown. An additional bone, which looks as though it had been segmented off from the jugal, appears, however, between the jugal and postorbital; its surface is marked in the same way as the jugal; and it bears a nutritive foramen, which completes the ascending series of these openings carried by the jugal. The suture between the two bones is distinct, however; and the striations on their surface are so directed as to indicate their separate nature. If a posterior supraorbital bone had worked its way in between the jugal and the postorbital, it would have the position here described; but simulation of the appearance of the jugal bone would remain unexplained. Hence it seems best to call it a suprajugal.

The jugal and the suprajugal bones are not the simple bony plates which they appear to be in a lateral view of the skull, and as the jugal really is in recent Lacertilia. Both extend inwards behind the orbit as a bony plate, which meets and joins externally with a similar expansion of the parietal. In this way the orbit is completely walled in behind. The maxilla similarly extends inwards in front, no doubt accompanied by the lacrymal; and, below, a continuous floor is afforded by the expanded palatine. The orbit is consequently very thoroughly walled round.

The right orbit is incomplete; and a horizontal fracture enables us to remove the jugal, the only outer boundary bone of it remaining, from the floor of the skull below. The jugal thus removed is a triradiate bone—when looked at from below, something like the letter ⊥. The crossbar of the T corresponds to the outer plate of the jugal, the stem to the process which extends from it inwards. The inner plate or process of the jugal does not join the outer bone abruptly, but curves outwards on each side into it. Thus a triangular space of considerable size is left at the junction of the two parts, or, in other words, at the origin of the inner plate. This space is occupied by coarsely cancellous bone, and lies immediately under the nutritive foramina, which occur on the outside of the proper jugal bone. The meaning of these foramina is thus made clear.

The floor exposed by the removal of the jugal is very difficult to interpret. Immediately behind the palatine is a narrow bone, transverse to the axis of the skull, and apparently joining the posterior edge of the palatine. Behind this, again, is a flat parallel-sided bar or lath of bone, projecting from the middle of the skull outwards at right angles to the axis; it is united by a splintery suture with the inner margin of a large and important bone, which extends backwards, prolonging the line of the maxillæ towards the quadrate. It consists of a vertical wall-sided outer plate, roughened on the external surface (which is a flat plane), and an interior horizontal plate, the inner angle formed by the divergence of the two plates being neatly rounded into a concave curve. The inner margin of the horizontal plate is a deeply concave curve.

The vertical plate of a bone having a similar position is shown in the right side of the ventral surface of a skull numbered 14550 in the British Museum. I do not know what to make of this bone; but it appears to be that which Prof. Huxley has spoken of as quadrato-jugal in his paper on *P. Etheridgii*.

The posterior part of the skull of *P. brachycephalus* covers over the axis and atlas vertebræ. It consists of the parietal and the ends of the two bones which have been called suprasquamosal. They join in a splintery suture over the middle of the parietal, and appear likewise to underlap it below; so that this bone appears to proceed from between the upper and lower tables of the suprasquamosal bones. This is a very singular feature; but as I have been able to examine this posterior fragment of the skull on all sides, and partly to take it to pieces, I entertain little doubt as to its existence.

2. *Redetermination of Measurements.*—Professor Owen says that the vertebræ, at least as far as the 28th, are cervical; but a careful examination leads me to include the 29th as an indubitable cervical vertebra. The succeeding vertebræ have lost a slice from their exposed sides; but there is good reason to conclude that the 30th and 31st also belong to the neck. The length of the cervical series is, then, as follows:—

I and II concealed + III to XXIX undoubted cervicals + XXX and XXXI doubtful.
1·5 inch + 36 inches + 3·5 inches

=41 inches or 3 feet 5 inches.

The remaining measurements are given in the appended Table (p. 477).

Geological Horizon.—Associated with this specimen, which came from the Lias of Bitton, are some Ammonites and *Rhynchonellæ*, which Mr. Whidborne regards as *A. Conybeari* and *R. variabilis*; hence he refers it to the *A.-Bucklandi* zone.

In concluding this paper, I have to offer my best thanks to Mr. Etheridge and Dr. Henry Woodward for the kind assistance they have given me in many ways; to Mr. Whidborne I am especially indebted for much useful help, and particularly for his care and assiduity in drawing up the appended list of species, with their geological positions, many of which have been determined by his own personal examination of the original types.

EXPLANATION OF PLATES XXIII. & XXIV.

Plate XXIII.

Plesiosaurus Conybeari.

Fig. 1. Ventral aspect of the skeleton. One twelfth nat. size.
2. Dorsal aspect, showing the vertebral column from the thirty-seventh (xxxvii) to the sixty-third (lxiii) vertebræ. About one eleventh nat. size.
3. Diagrammatic restoration of the pectoral girdle. One eighth nat. size.
4. Diagrammatic restoration of the pelvic girdle, the ilia not being represented. One eighth nat. size.

Plate XXIV.

Fig. 1. Skull of *P. Conybeari*, left side. About one fourth nat. size.
2. Skeleton of *P. brachycephalus*, Owen. About one twelfth nat. size.

Discussion.

Prof. Seeley said that without an inspection of the evidence he was not in a position to criticise this elaborate paper; but it gave evidence of painstaking research of no ordinary kind, and he congratulated the author upon what he had put forward. He thought, however, that a part of the information was not entirely new. Still the species, he fully believed, was a new one, as several of the characteristics are not found in any other described Plesiosaur. He had an impression that the palatal foramina described by Prof. Sollas were shown in the species described by Mr. Stutchbury fourteen years ago; and he believed they had been excavated after that description had been drawn up. As to the Lacertilian affinities of *Plesiosaurus*, he was unable himself, so far as he had seen, to recognize any of importance. In some respects it had affinities with Ichthyosaurs, Dinosaurs, and Crocodiles; so he thought the Lacertilian affinities could not be pressed. Though he differed in some details, he thought the paper, as a whole, was done extremely well.

TABULAR SYNOPSIS OF THE GEOGRAPHICAL DISTRIBUTION OF THE PLESIOSAURS. BY G. F. WHIDBORNE, Esq., F.G.S.

Table I.—*English Species.*

* =Vertebræ. † =Bones of the limbs, thorax, or pelvis. ‡ =Skull. § =Skeleton. ‖ =Imperfect skeleton. ¶ =Teeth.

	Date.	Horizon.	Locality.	Defined genus.	Description.	References.	Museums.	
PLESIOSAURUS (*Conybeare*)	1821.							
RHÆTIC.								
*costatus (*Owen*)	1839	Bone-bed	Aust.		Owen, Brit. Assoc. Rep. 1839, p. 80	12	*Bristol.	
*Hawkinsi (*Owen*)	......	Bone-bed	Aust.					See "Lower Lias."
*rugosus (*Owen*)	......	Bone-bed	Aust.	Eretmosaurus			*Bristol	See "Lower Lias."
*trigonus (*Cuvier*)	1825	Bone-bed	Aust; *Calvados*		Cuv Os Foss. vol ii. p. 486	5, 12		
LOWER LIAS.								
‡†*arcuatus (*Owen*)	1839	Planorbis?	Street, Bitton, Charlton		Owen, Brit. Ass. Rep. 1839, p. 75	4, 12	British, *Bristol, Enniskillen, Woodwardian.	Figured in Geol. Trans. ser. 2, vol. v. p. 44. "Not from Whitby or Wurtemburg," *Owen.*
§brachycephalus (*Owen*)	1839	Turneri	Bitton; *Boll*		Owen, Brit. Ass. Rep. 1839, p. 69	30 31, 12	Bristol (3 specimens)	With *Rhynchonella variabilis* (Schloth.) and *Ammonites obliquecostatus* (Ziet.) = *A. semicostatus* (T. & B.). See Wright, Q. J. G. S. vol. xvi. p. 406.
‖cliduchus (*Seeley*)	1865	Planorbis?	Street		Seeley, Ann. & Mag. N. H. ser. 3, vol. xvi. p. 352	25	Woodwardian.	
§Conybeari (*Sollas*)	1881	Obtusus	Charmouth	Restricted genus	Sollas, described here	13	Bristol, British	Found with *Ammonites planicostatus*, Sow. Min. Con. 148, one of the most frequent Ammonites of the Marston stone, as well as the Charmouth beds of this zone.
§dolichodeirus (*Conybeare*)	1824	Planorbis	Watchet, Bath, Bristol, Bitton, Lyme, Charmouth.	Type of genus	Conybeare, Geol Trans. ser. 1, vol ii. t 18, 49	3, 4, 5, 12, 18	British (3 specimens)	"Figured in Bridgwater Treatise."
‖eleutheraxon (*Seeley*)	1865	Planorbis?	Street		Seeley, Ann & Mag N H ser 3, vol. xvi p 352	25	Woodwardian.	
§Etheridgii (*Huxley*)	1858	Ostrea-beds	Street		Huxley, Q. J. G. S. vol. xiv. p 281	33	Jermyn Street.	
§Hawkinsi (*Owen*)	1838	Ostrea-beds	Street, Lyme, Weston	Restricted genus	Owen Geol Trans ser 2 vol v. p. 515	5, 6, 12, 18 33	British	Syn. *triatarsostinus* (Hawkins).
§macrocephalus (*Conybeare*)	1836	Planorbis	Street, Lyme, Weston		Buckland Bridgewater Treatise, vol ii p 32	4, 5 12	Enniskillen.	
‖macromus (*Owen*)	1839	"Marl"	Near Lyme		Owen, Brit Ass Rep 1839, p 72	8, 12	Coll. "Miss Phillpots".	Quoted by Stutchbury as "*macrourus*."
§megacephalus (*Stutchbury*)	1846	Ostrea-beds. Angulatus	Street, Wilmcote, Warwick		Stutchbury, Q. J G S vol ii p 411	12, 27, 33	Bristol, Warwick.	
§rostratus (*Owen*)	1865	Bucklandi	Charmouth		Owen Pal. Soc., Liassic Rep p 20	22	British	"The most perfectly preserved specimen known."
§rugosus (*Owen*)	1839	Angulatus; Planorbis, Bucklandi; Obtusus	Cliff (Yorkshire); Lyme, Weston; §Granby (Leicestershire)	Eretmosaurus	Owen, Brit. Ass. Rep. 1839, p. 82	15 23, 30, 31, 33	§British, *Enniskillen, †Bristol, (York?)	"Whitby," Owen & Phillips, not Tate & Blake. The Granby skeleton found with *A. stellaris.*
*subtrigonus (*Owen*)	1839	Bucklandi?	Weston (near Bath)		Owen, Brit. Ass. Rep. 1839, p. 77	12	*Bristol.	
MIDDLE LIAS.								
*sp. indet	1876	Capricornis	Saltburn		Tate & Blake, Yorkshire Lias, p. 252.			
*sp. indet.	1876	Jamesoni	Huntcliff		Tate & Blake, Yorkshire Lias, p. 252.			
UPPER LIAS.								
*brachycephalus (*Owen*)	......						York (*Owen*)	"Whitby," Owen, not Tate & Blake. See Lower Lias.
§Cramptoni (*Carte & Baily*)	1863	Upper part of Bifrons	Kettleness (near Whitby)	Rhomaleosaurus (*Seeley*)	Carte & Baily, Dubl. Roy. Soc. Journ. vol. iv. p. 160	21, 30, 31	Dublin	"60 ft. below Dogger, with numerous *Leda ovum.*"
*cœlospondylus (*Owen*)	1865	Communis	Whitby		Owen, Pal. Soc., Liassic Rep. p. 12	31	Whitby	"They perhaps belong to *P. longirostris*" (T. & B.).
†dubius (*Tate & Blake*)	1876	Communis		Eretmosaurus (*T. & B.*)	Tate & Blake, Yorkshire Lias, p. 246			"This is a synonym for *P. macropterus*, if the latter is an *Eretmosaurus.*"
§homalospondylus (*Owen*)	1865	Bifrons	Whitby		Owen, Pal. Soc., Liassic Rep. p. 12	21, 30, 31, 33	British, York, *Whitby	In beds with *Ammonites heterophyllus.*
§longirostris (*Tate & Blake*)	1876	Serpentinus	Whitby		Tate & Blake, Yorkshire Lias, p. 250.			
§macropterus (*Seeley*)	1865	Communis	Lofthouse	Eretmosaurus?? (*T. & B.*)	Seeley, Ann. & Mag. N. H. ser. 3, vol. xv. p. 49	31	Woodwardian	= *P. grandipennis* (MSS.).
§propinquus (*Tate & Blake*)	1876	Serpentinus	Whitby		Tate & Blake, Yorkshire Lias, p. 249	19	Whitby	Founded on a specimen labelled "*macrocephalus.*"
[illegible] (*Owen*)	......			Eretmosaurus				See Lower Lias.
zetlandicus (*Phillips*)	1854	Communis	Lofthouse		Rep. Yorksh. Phil. Soc. 1854	19, 30, 31	York.	
LOWER OOLITE.								
*¶serraticus (*Phillips*)	1871	Stonesfield Slate	Stonesfield		Phillips, Valley of Thames, p. 180			A small species.
sp.	1869	Great Oolite	Minchinhampton		Seeley, Cat. of Rept. & Birds, p. 119		Woodwardian.	
MIDDLE OOLITE.								
†eurymerus (*Phil.*)	1871	Oxford Clay	Bedford		Phillips, Valley of Thames, p. 314		Woodwardian	Near *Pl. dædicomus.*
§Leedsii (*Seeley*)	1874	Lower Oxford Clay	Huntingdonshire	Murænosaurus (*Seeley*)	Seeley, Q. J. G. S. vol. xxx. p. 197	27	Coll. Leeds	With *Am. Duncani, Lamberti,* &c. It is the same specimen as the "*Plesiosaurus grandis?*" of Phillips, Valley of Thames, p. 318.
‖oxoniensis (*Phil.*)	1871	Oxford & Ampthill Clay	Oxford, Long Marston	Murænosaurus	Phillips, Valley of Thames, p. 307	29.		
philarchus (*Seeley, MS.*)	1869	Oxford Clay	Peterborough		Seeley, Cat. of Rept. & Birds, p. 139		Woodwardian.	
*plicatus (*Phil.*)	1871	Oxford Clay		"Ellipsospondylic group"	Phillips, Valley of Thames p 313			
KIMMERIDGE CLAY.								
†affinis (*Owen*)	1839	Kimmeridge Clay	Heddington, Shotover		Owen, B. A. Rep. 1839, p. 86	12, 27	Enniskillen.	
*brachistospondylus (*Hulke*)	1870	Kimmeridge Clay	Kimmeridge Bay		Hulke, Q. J. G. S. vol. xxvi. p. 611			
*brachyspondylus (*Owen*)	1839	Kimmeridge Clay	Heddington, Shotover, near Weymouth, Foxmouth		Owen, B. A. Rep. 1839, p. 78	1, 12, 25, 27	Oxford, Bristol, Woodwardian	'Syn. *Pl. recentior*? (Conyb. & Von Meyer), and *Pl. giganteus*? (Conyb. 1824)," Owen.
†dædicomus (*Owen*)	1839	Kimmeridge Clay	Shotover		Owen, B. A. Rep. 1839, p. 82	12 27		
*ellipsospondylus (*Owen*)		Kimmeridge Clay.			Phillips, Valley of Thames, p. 372		Oxford.	
*hexagonalis (*Phil.*)	1871	Kimmeridge Clay	Cowley clay pits		Phillips, Valley of Thames, p. 375			
*infraplanus (*Phil.*)	1871	Kimmeridge Clay	Shotover, Stanford, Brill		Phillips, Valley of Thames, p. 375			
‖Mansellii (*Hulke*)	1870	Kimmeridge Clay	Kimmeridge Bay	Murænosaurus	Hulke, Q. J. G. S. vol. xxvi. p. 611	29	British & Coll. Mansell	
megadeirus (*Seeley*)	1869	Kimmeridge Clay	Ely	Colymbosaurus	Seeley, Cat. of Rept. & Birds, p. 97	24, 29	Woodwardian.	
*plicatus (*Phil.*), "allied to"	1871	Kimmeridge Clay	Shotover	Ellipsospondylic group	Phillips, Valley of Thames, pp. 373, 374		Oxford	See Oxford Clay. It is doubtful whether Phillips makes two or a single species here.
*validus (*Phil.*)	1871	Kimmeridge Clay	Shotover, Cumnor, Baldon		Phillips, Valley of Thames, p. 370			
PORTLAND BEDS.								
*carinatus (*Phil.*)	1871	Portland Rock	Quainton (Bucks)		Phillips, Valley of Thames, p. 374			Small vertebræ, probably but not certainly from Portland Rock. If Cuvier's name stands, this should become *Pl. Phillipsi.*
*winspitensis (*Seeley*)	1871	Portland Limestone	Winspit (I. of Purbeck)	Colymbosaurus (*Seeley*?)	Seeley, Ann. & Mag. Nat. Hist. ser. 4, vol. viii. p. 181			"It approaches *Pl. megadeirus,*" Seeley.
CRETACEOUS.								
*Bernardi (*Owen*)	1850	Neocomian to Upper Chalk	Reach, Arundel; *Moscow.*		Dixon, Foss. Sussex, p. 396	10, 11, 12, 15	British.	
*constrictus (*Owen*)	1850	Chalk	Steyning (Kent)		Dixon, Foss Sussex, p. 398	11, 12		
§Gardneri (*Seeley*)	1877	Gault	Folkestone	Mauisaurus	Seeley, Q. J. G. S. vol. xxxiii. p. 541		Coll Gardner	The largest long-necked Plesiosaur known
*†latispinus (*Owen*)	1854	Lower Greensand	Iguanodon Quarry, Maidstone		Owen, Cat Foss. in Coll. Surgeons, p 63	11	British.	
*pachyomus (*Owen*)	1839	Upper Greensand	Reach (Cambridge)		Owen, B. A. Rep. 1839, p. 74	11, 12	Woodwardian.	
*planus (*Owen*)	1864	Greensand.	Cambridge, *Moscow*		Owen, Pal. Soc., Cret. Rep. Sup	15, 25	Woodwardian, British.	
neocomiensis (*Campiche*)	1858; 1860	Upper Greensand; Lower Neocomian	Cambridge; *Ste. Croix; Moscow*		Pictet & Campiche, Foss. Crét. de Ste. Croix, ser. 2, pp. 42 46.	11, 15	British, Woodwardian	Syn. "*Pl. mamillatus* (Owen)."
sp.	1851	Bottom of L. Greensand	I. of Wight		Owen, Pal Soc, Cret Rep t 20 f 7		Coll. Lee.	
†sp.	1851	Chalk	Burnham		Owen, Pal Soc, Cret Rep t 19. f 17		Coll. Smith.	
PLIOSAURUS (*Owen*)	1841							
†æqualis (*Phil.*)	1871	Kimmeridge Clay	Near Swindon, Shotover		Phillips, Valley of Thames p 351		Oxford.	
§brachydeirus (*Owen*)	1840	Kimmeridge Clay	Market Raisin, Shotover		Owen, Odontography, p. 283	7, 12, 17, 25, 27	Oxford, Woodwardian	"Found with *Am. vertebralis*, which, however, occurs in Upper Oxford Clay at Cowley," Phil.
*gamma (*Owen, MSS.*)	1872	Oxford and Kim. Clay	Weymouth, Shotover		Phillips, Valley of Thames, p. 359		Oxford	
‡†¶grandis (*Owen*)	1839	Kimmeridge Clay	Shotover, Kimmeridge, &c.		Owen, B. A. Rep. 1839, p. 83	17, 27	Oxford, British.	
‖Evansi (*Seeley*)	1877	Lower Oxford Clay	Eynesbury, near St. Neotts	"Genus doubtful"	Seeley, Q. J. G. S. vol. xxxiii. p. 717	25	Woodwardian	
*†macromerus (*Phil.*)	1871	Kimmeridge Clay	Swindon, Shotover		Phillips, Valley of Thames, p. 354		Oxford.	Found with *Am. Duncani, Lamberti,* &c.
*nitidus (*Phil.*)	1871	Kimmeridge Clay	Shotover		Phillips, Valley of Thames, p. 360			
pachydeirus (*Seeley, MSS.*)		Oxford Clay	Great Grandson		Seeley, Cat. Rept. & Birds, p. 116		Woodwardian.	
*†portlandicus (*Owen*)	1869	Portland Limestone	I. of Portland		Owen, Pal. Soc., Kim. Clay Rept. pt. 3, p. 8		British.	
†simplex (*Phil.*)	1871	Oxford and Kimmeridge Clay and Coral Rag	Shotover		Phillips, Valley of Thames, p. 366		Oxford.	
sterrodeirus (*Seeley, MSS.*)	1869	Kimmeridge Clay			Seeley, Cat. Rep. & Birds, p. 98		Woodwardian	
‡†trochanterius (*Owen*)	1839	Oxford and Kim. Clay	Christian Malford, Kimmeridge, Foxcombe	Or "new genus" (*Ow.* Kim. C. R.).	Owen, B. A. Rep 1839, p 85	7, 12, 17, 27	Enniskillen, Oxford, British.	
¶sp.	1866	Shanklin Sand	Bedfordshire		Seeley, Ann. & Mag. Nat. Hist. ser. 3, vol. xviii. p. 112			
POLYPTYCHODON (*Owen*)	1840							
*†¶continuus (*Owen*)	1840	L. Greensand and Chalk	Maidstone, Sussex; *Moscow*		Owen, Odontography, vol. ii. p. 19.	10, 11, 12, 15	British.	
*‡¶interruptus (*Owen*)	1840	Upper Greensand, Lower and Middle Chalk	Cambridge, Frome, &c.; *Moscow*		Owen, Odontography, vol. ii. p. 19	10, 11, 12, 15	Woodwardian.	

Table II.—*Foreign Species.*

PLESIOSAURUS.					
australis (*Owen*)	1861	Oolite	Australia	Owen, Brit. As. Rep. 1861, p. 122	26.
carinatus (*Cuvier*)	1825	Oolite	Boulonnais	Cuv. Os. Foss. vol. ii. p. 436	9. "Provisionally named," Cuv
chilensis (*Gay*)	..		Bay of Concepcion	Blake, Geol. Mag. 1862.	
crassicostatus (*Owen*)	1870	Triassic?	Waipara Beds (Australia)	Owen, Geol. Mag. vol. vii. p. 49.	
Fahrnkohlii (*Fisch.*)	1846	Grès Neocom.	Moscow	Fisch. Bull. de Moscou, 1846	15.
Hoodii (*Owen*)	1870	Triassic	Waipara Beds	Owen, Geol. Mag. vol. vii. p. 49.	
indicus (*Lydekker*)	1876	Oolite	Kach	Lydekker, Rep. Geol. Surv. Ind. vol. x. [p. 30	
jenensis (*Zenk.*)	...			Zenk. Beitr. Urw. p. 65	9.
Nordmanni (*Eichwald*)	1859?	Grès Neocom.	Crimea	D'Eichwald, Lethæa Rossica, p. 1276.	
pentagonus (*Cuv.*)	1825		Honfleur	Cuvier, Os. Foss. vol. ii. p. 486	9.
profundus (*Zenk.*)	...			Zenk. Beitr. Urw. 64, t. 6	9.
suevicus (Quen.)	1848	Braun a...	Hagenbach	Quenstedt, Der Jura, pp. 216, 322.	
sp.	1858	Humph. Zone	Hillhausen	Quenstedt, Der Jura, t. 53. f. 3.	

ELASMOSAURUS.					
platyurus (*Cope*)	...			Seeley, Q. J. G. S. vol. xxxiii. p. 541.	
serpentinus (*Cope*)	1877		Niobrara	Cope, Bull. U.S. Surv. vol. iii. no. 3, p. 505.	
MAUISAURUS.					
Haasti (*Hector*)	1874	Cretaceous	New Zealand	Trans. N.Z. Inst. vol. vi. p. 20	32.
PLIOSAURUS.					
brachyspondylus (*Owen*)	...	Cretaceous	Russia	D'Eichwald, Lethæa Rossica, p. 1280	Probably an error? 15.
Wosinskii (*Fisch.*)	1846	Neocomian	Near Moscow	Fisch. Bull. de Moscou, vol. i. pp. 11, 105	15.
RHINOSAURUS.					
Jasykowii (*Fisch.*)	1847	Neocomian	Near Moscow	Fisch. Bull. de Moscou, vol. i. p. 362	15.

Books and Papers referred to in the foregoing List.

1. 1821 Conyb. Geol. Trans. ser. 2, vol. i. p. 103. On *Pl. dolichodeirus.*
2. 1825 Cuvier, Os. Foss. vol. ii.
3. 1836 Buckland, Bridgewater Treatise. On *Pl. macrocephalus* &c.
4. 1838 Owen, Geol. Trans. ser. 2, vol. v. p. 515. On *Pl. macrocephalus.*
5. 1839. Owen, Brit. Association Rep. p. 43.
6. 1840 Hawkins, Great Sea-Dragons.
7. 1841 Owen, Brit. Assn. Rep. p. 60.
8. 1846. Stutchbury, Q. J. G. S., vol. ii. p. 411. On *Pl. megacephalus.*
9. 1848 Bronn, Index Pal.
10. 1851. Owen, Brit. Assn. Rep.
10. 1850. Owen, in Dixon's Foss. of Sussex.
11. 1851-2 Owen, Pal. Soc. Cret. Rep
12. 1854 Morris, Brit. Fossils.
13. 1858 Huxley, Q. J. G. S., vol. xiv. p. 281. On *Pl. Etheridgii*
14. 1858. Quenstedt, der Jura.
15. 1859. D'Eichwald, Lethæa Rossica, vol. ii. sect. 2.
16. 1861. Owen, Brit. Assn. Rep. p. 122.
17. 1861–69. Owen, Pal. Soc., Kim. Clay Rept.
18. 1861–70. Owen, Pal. Soc., Liassic Rept.
19. 1866. Carte and Baily, Dublin Roy. Soc. Jour. vol. iv. p. 160. On *Pl. Cramptoni.*
20. 1864. Geol. Mag. p. 47.
21. 1865. Seeley, An. M. N. H. ser. 3, vol. xv. pp. 49 & 232. On *Pl. macropterus.* vol. xvi. p. 352. On *Pl. eleutheraxon* & *Pl.* [illegible]
22. 1867. Geol. Mag. p. 144.
23. 1867. Moore, Q. J. G. S., vol. xxiii. p. 448. Abnormal Secondary Deposits.
24. 1870. Hulke, Q. J. G. S., vol. xxvi. p. 611. On *Pl. brachistospondylus* and *M. Mansellii*
25. Seeley, Woodwardian Catalogue of Rept. and Birds.
26. 1870. Owen, Geol. Mag. vol. vii. p. 49. On Saurians from New Zealand.
27. 1871 Phillips, Valley of Thames.
28. 1871 Seeley, An. M. N. H. ser. 4, vol. viii. On *Pl. winspitensis.*
29. 1874 Seeley, Q. J. G. S. vol. xxx. p. 197, on *Murænosaurus Leedsii*, p. 436, on the Plesiosaurian Pectoral Arch.
30. 1875. Phillips, Geology of Yorkshire, ed 2.
31. 1876. Tate and Blake, Geology of Yorkshire.
32. 1877. Seeley, Q. J. G. S. vol. xxxiii. p. 541, on *Maui. Gardneri*; p. 716, on *Plio. Evansii.*
33. 1878. Wright, Lias Ammonites.

Notices of Plesiosauri also occur in the following works.

1821. De la Beche and Conybeare on *Plesiosaurus*, Geol. Trans. ser. 1, vol. v. p. 560.
1837. Pusch, Polens Palæontologie (?).
1846–47. Fischer, Bulletin de Moscou.
1850. Owen, Odontography.
Gay, Historia fisica y politica de Chile.
1859. Pictet et Campiche, Fossiles du terrain Crétacé des environs de Ste. Croix.
1859. Lucas Barrett, An. & M. N. H. 1858
1860. Owen, Palæontology.
1874. Hector, New-Zealand Inst. vol. vi.
1876. Lydekker, Rep Geol. Surv. India, vol. x. p. 30.

NOTE.—Hawkins, in (6), has two fine figures; but his names being generic and apparently merged by Owen in his Report (1839 and 1841), it has not been possible to refer to them in the tables. Prof. Seeley, in Q. J. G. S., vol. xxxiii. p. 442, notes the following genera:—(1) from the Cambridge Greensand, [illegible], (2) from the Rhætic, *Placodus* (coll. Moore) and *Tanystrophæus* (coll. Plant). Owen's 'Palæontology' and Von Meyer's 'Palæontographica' give many other foreign species and genera from the European Trias. There are said to be none from that of America. Table II does not aim at being a complete list.

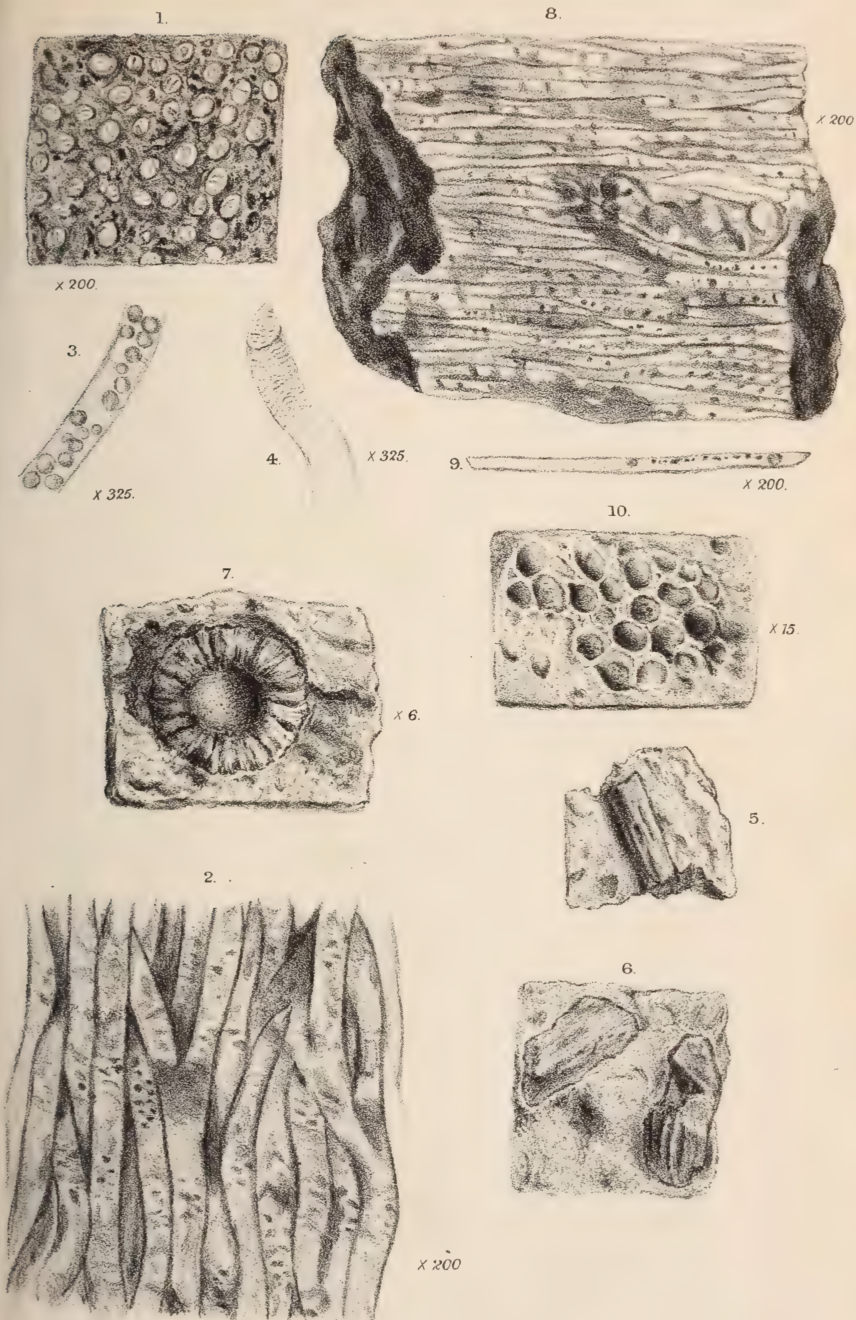
Omitting the most uncertain species, Table I gives 23 Rhætic and Liassic, 34 Oolitic, and 9 Cretaceous—making a total of 63 English species hitherto named or described. There is, however, at present no reason to suppose that some of the names are not synonyms.

Prof. Sollas expressed his sense of the generous way in which Prof. Seeley had spoken of his paper. It was impossible to write a paper without making use of material already published; but he thought that there was but little put forward as new which was not really so in his paper. He thought the Lacertilian affinities were extremely well marked in the skull of *Plesiosaurus*. His determination of the structure of the anterior part of the roof of the mouth in *P. megacephalus* confirmed him in this opinion.

37. *On the* Discovery *of some* Remains *of* Plants *at the* Base *of the* Denbighshire Grits, *near* Corwen, North Wales. By Henry Hicks, Esq., M.D., F.G.S. *With an Appendix* by R. Etheridge, Esq., F.R.S., Pres. Geol. Soc. (Read May 25, 1881.)

[Plate XXV.]

In August 1875, when searching for fossils in the Pen-y-Glog slate-quarry, which is situated about two miles to the east of Corwen, I noticed some carbonaceous-looking fragments and markings on the shales in association with the massive grit beds towards the top of the quarry, which I thought at the time might possibly be plant-remains. Last summer I had another favourable opportunity of examining these beds; and I was fortunate enough to discover undoubted plant-remains scattered very abundantly over their surfaces. I submitted these for further examination to Mr. Carruthers, of the British Museum, and had the satisfaction to find that he entirely confirmed my views as to their nature. He said they were undoubtedly "angular fragments of plants," but that the specimens were not in a sufficiently satisfactory condition to determine the actual plants to which they belonged. I decided, therefore, not to bring the matter before the Society until I had another opportunity of visiting the quarry and of endeavouring to procure more perfect specimens. This I was able to do lately; and the additional materials now found have proved to exhibit structures sufficiently well marked to enable a very clear identification of several distinct plants to be made out. The specimens have been generally examined by Mr. Carruthers, and some specially by Mr. Etheridge and Mr. Newton, of the Jermyn-Street Museum. Amongst them have been found numerous small spherical bodies identical in general appearance, and in internal structure, with the *Pachytheca* described by Sir J. D. Hooker, from the bone-bed at the top of the Ludlow series. These are supposed to be the remains of spore-cases of land plants belonging to the order Lycopodiaceæ; other specimens are supposed by Mr. Carruthers to be the microspores, and others to be fragments of the stems of the same plants. Some of the specimens would indicate the presence also of plants belonging to the genus *Psilophyton.* These, though tolerably abundant, occur chiefly as carbonaceous markings, and show little evidence of structure. The combined results are sufficient to make it clear that we have here a terrestrial flora of a tolerably high order. The majority of the fragments, however, belong to a curious plant not hitherto found in Great Britain. It was first discovered by Sir W. Logan in the Devonian rocks, in the peninsula of Gaspé, Lower Canada, and described by Dr. Dawson, of Montreal, in the Quart. Journ. Geol. Soc. for 1859, under the name *Prototaxites.* Dr. Dawson described it as a land plant of large size, belonging



A. S. Foord lith.

Mintern Bros. imp.

SILURIAN PLANT REMAINS.

to the Coniferæ, but yet differing from any Conifer known to him "in the cylindrical form and loose aggregation of the wood cells, as seen in the cross section, in which particular it more nearly resembles the young succulent twigs of some modern Conifers than their mature wood." He maintained, however, that it was an "exogenous tree, with bark, rings of growth, medullary rays, and well-developed though peculiar woody tissue "*.

Mr. Carruthers subsequently examined the same plant and re-described it in an elaborate paper in the Monthly Microscopical Journal for October 1872, and gave numerous reasons for excluding it not only from the Coniferæ, but from land plants altogether, and for placing it in preference among the Algæ. In doing so, however, he said it was an "anomalous Alga, and, indeed, that with the materials known, it was not possible to correlate it with certainty with any known group of Algæ." The identity of our plant with the above mentioned, which was re-named by Mr. Carruthers *Nematophycus*, is placed beyond doubt by the following note kindly given me by Mr. Carruthers:—

"The slides prepared by Mr. Newton show clearly that his determination of the fragments of charcoal and petrified remains of plants in the Silurian rocks which you have found, belong to the same type of plants as that discovered by Logan at Gaspé, in beds which he considered to be of Devonian age. This was described by Principal Dawson in the Quart. Journ. Geol. Soc. (vol. xv.) under the name *Prototaxites Logani*. I made a careful examination of specimens which I owed to the kindness of Dr. Dawson, and published the results of this examination in the Monthly Microscopical Journal, giving the reasons for placing it among cellular plants and naming it *Nematophycus Logani*. The specimens show very distinctly the larger tubes of *Nematophycus*, running generally in a subparallel direction, but passing in and out amongst each other. The walls are not in juxtaposition, leaving free space all around them, which was occupied, as is shown in the better-preserved specimens from Gaspé, with a dense tissue of more delicate tubes of smaller dimensions. That your specimens belong to the plant called *Nematophycus* I have no doubt. The conditions under which they are found are very different from those described by Dr. Dawson. His specimens were large trunks, sometimes perfectly silicified and preserving their most minute structures. Your specimens, consisting of small fragments, consequently supply no help to the further knowledge of this remarkable plant, unless the occurrence on the same slab, in tolerable abundance, of small round bodies having the same form and structure as those found in the Ludlow bone-bed, which were figured and described by Sir J. D. Hooker under the name *Pachytheca*, indicate some possible relationship. The specimens found by you are perhaps smaller than those from Ludlow. They present no indication of attachment, and no evidence of their relation to *Nematophycus*, except their being found together, which is not always a good basis for structural re-

* 'American Naturalist,' vol. v. p. 245.

lations in fossil plants. The minute bodies, aggregated together, which you have also shown me are, I believe, spores; and as they are united in threes, they agree with the forms of the microspores of Lycopodiaceæ, both recent and fossil, and testify to the existence of a dry-land flora. Perhaps some of the anthracite fragments may belong to the stems of the plants of which these are the reproductive organs. The ribbon-like carbonaceous impressions, with a slender axis, must have been also dry-land plants; they remind me of the plants discovered and described by Principal Dawson, C.M.G., as *Psilophyton*.

"W. CARRUTHERS."

The specimens found, hitherto, of *Nematophycus* are all in a fragmentary condition, the largest pieces being generally under 2 inches in length, and a little over half an inch in thickness. The natural outline, however, is frequently preserved; and if the majority of the fragments are any guide to the natural size of the mature plant, it is evident it must have been small as compared with the Devonian one of Sir W. Logan, which attained to over a foot in diameter. That the plant must have been plentiful at this early period is clear from the very great abundance of the fragments in some of the beds; sometimes so closely compressed together are they, that they form an actual carbonaceous seam from one to two inches in thickness.

The microscopical characters of this plant, which are peculiarly interesting, will be fully referred to in the Appendix by Mr. Etheridge *.

The discovery of *Pachytheca* and other spore-like bodies in considerable abundance in association with *Nematophycus* is curious, but, as remarked by Mr. Carruthers, is no direct evidence of their relationship. We know, moreover, from geological evidence, that the shoreline at the time could not have been very far distant, and therefore that it is quite possible there may be here a mixture of marine and dry-land plants. The broken condition of the specimens also tends to show that none of them lived in the actual positions in which they are now found, but that they were brought here by some accidental cause, possibly along with a great amount of sediment, and as the result of river-floods, or of depression followed by rapid marine denudation.

The almost abrupt appearance at this horizon of massive beds of grits upon fine muddy deposits of considerable thickness, such as the slates immediately below, evidently tends to show that a physical change was then taking place in some neighbouring area; but besides this there is nothing to indicate a physical break at this point.

* Dr. Dawson, in his reply to Mr. Carruthers, 'Monthly Microscopical Journal,' 1873, still insists on his former diagnoses; and in a letter addressed to me, dated June 16th, 1881, in reference to the published abstract of this paper, says:—"I have perfect confidence in my genera *Prototaxites*, *Nematoxylon*, and *Celluloxylon*, as representing primitive types of land plants; and I maintain my judgment as to these genera, and I believe it will be vindicated by future discoveries."

In addition to the above-mentioned tolerably well-preserved plant-remains from the shales associated with the grits, there are undoubted evidences of a still earlier and probably equally important flora in beds of slate at the base of the quarry. Instead, however, of the remains being preserved chiefly in the condition of mineral charcoal, as in the upper beds, they occur here mainly in the state of a very pure anthracite. At the same horizon some large nodules are seen; and in the centre of these anthracite is also occasionally found, evidently forming the nucleus. From some of the specimens examined, I conclude there can be no doubt that these plants must have been of considerable size; and the amount of carbon left on some of the surfaces, apparently from a single fragment only, would tend to show, as suggested by Mr. Carruthers, that it must have been derived from vascular plants. There can be little doubt, therefore, that there is in the slates and nodules, even in the so-called Tarannon slates, very clear evidence of a terrestrial flora of considerable importance*. The anthracite, as now found, is usually broken into innumerable small fragments; but it is perfectly clear that this must be due to changes to which it has been subjected since it was deposited—changes which also produced induration, cleavage, and fractures in the argillaceous sediments. The fissures in the anthracite, and in the charcoal in the other beds, are generally filled by a fibrous mineral, which occurs here in some places in considerable abundance. Mr. T. Davis has kindly examined this, and says that it is a "fibrous form of a hydrated magnesian silicate." In other cases the fissures are filled with calcite.

The difference in the conditions of fossilization in which the remains are now found at the two chief horizons may doubtless be to a great extent explained by taking into consideration the manner in which they were imbedded in the deposits. The thick grit-beds were evidently thrown down rapidly, and covered over the fragments before decomposition had taken place in them to any great extent. The fine muddy deposits which compose the slates were evidently thrown down much more slowly, and in a tolerably quiet sea; therefore vegetable material resting on the bottom would have time to decompose almost completely before it would be sufficiently covered over by the deposits. To a certain extent the same cause has allowed remains of vascular plants only to be preserved, as cellular ones would be too readily and too completely destroyed to show indications of their presence in such deposits. This is, I believe, the reason why remains of Algæ are not more frequently found in these older rocks, and why impressions only are seen in most cases.

The Pen-y-Glog quarry, where the specimens were obtained, has

* Since this paper was read I have received from Mr. Phillips, the manager of Pen-y-Glog quarry, to whom I am indebted for much assistance, specimens which show clearly that plant-remains occur in the pale shales below the Denbigh-grit series in the same state of preservation as in the beds at the top of the quarry. These shales also contain numerous calcareous nodules.

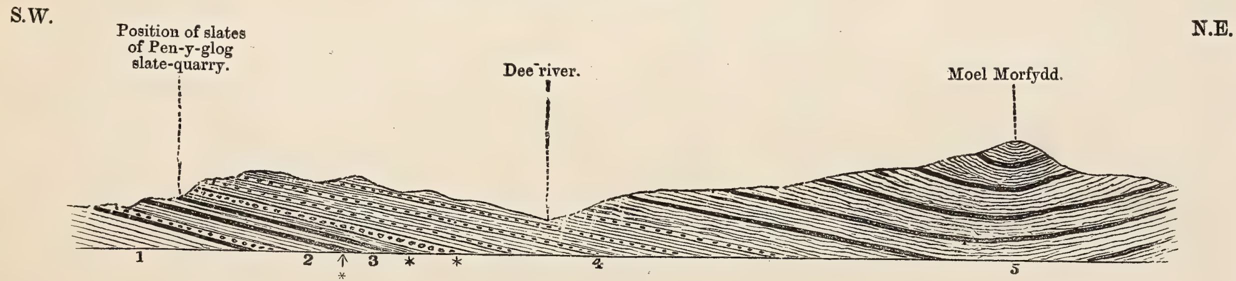
been already referred to in several papers read before this Society; and its geological position is therefore well known. In the Survey maps and sections its horizon is given as immediately at the base of the Denbigh-grit and Flag series. It is shown to be separated from the Bala or Caradoc beds by only a very thin band of shales, which also contain plant-remains. In the published sections across this neighbourhood approximate thicknesses of between 4000 and 5000 feet of beds belonging to the Denbighshire-grit and Wenlock series are shown to occur in direct superposition to the beds in which the plants are found. None of the beds belonging to the Ludlow series are mentioned as occurring in these sections, the highest given being Wenlock: hence, if the former were deposited in this area, they have all been since removed by denudation.

The geological horizon of the plant-yielding beds in relation to typical sections in other areas is rather difficult to define, since hitherto the Denbighshire-grit series has not been satisfactorily correlated with any other group. In the Survey sections the true Wenlock beds are made to come in at an horizon somewhere about 2000 feet above these beds, and to occupy the remainder of the sections. The only beds below the plant-beds which have been actually correlated by their fossil contents with those in other areas are the Bala and Lower Llandovery beds; hence, at present, the evidence goes to prove that they must be older than the Wenlock, and newer than the Lower Llandovery. In Mr. Ruddy's paper * the Lower Llandovery beds are said to be represented in this area by the Corwen-grit series of Prof. Hughes; and the latter, in summing up the evidence as to the succession in this section, says it goes to prove:—"that the Corwen grits are distinct from the Pen-y-Glog grits; that there is more evidence of a discordancy at their base than at the base of the pale slates or the Pen-y-Glog grits; that there are generally some beds of conglomerate, sandstone, or limestone with sandstone on the horizon of the Corwen grits; that the general facies of the few fossils obtained from these beds in the district examined is that of May-Hill rocks"†.

He states, further, that these Corwen grits are succeeded by beds which "pass up into the 'pale slates' of the Survey, which in turn pass up into the striped flaggy beds of Pen-y-Glog, on the top of which come grits, to be referred to the true Denbigh Flag and Grit series." As the latter are the higher beds mentioned where plants were obtained, we have ample evidence of their position in regard to the succession exhibited here, both from beds below and from those which rest upon them. In other areas the position occupied here by the Denbighshire flag and grit series, the pale slates, and the Corwen grits seems to be chiefly filled up by the Llandovery or May-Hill group and the Tarannon slates: the latter, I think, with the late Mr. Salter, however, should always be included in the May-Hill

* Quart. Journ. Geol. Soc. vol. xxxv. p. 200.
† Ibid. vol. xxxiii. p. 207.

Diagram Section from Nant Llechos, near Corwen, to Moel Morfydd. (Horizontal scale 1 inch to a mile. Vertical scale about 3000 feet to 1 inch.)



1. Bala beds.
2. Corwen Grits and Shales (Lower Llandovery).
3. Pale slates.
4. Denbigh Grit and Flag series.
5. Wenlock series.

* Chief positions of plant-remains.

↑ Base of Upper Silurian of Survey.

group. The accompanying section (p. 487) will explain more fully the succession in this area and the actual position of the chief beds containing the plant-remains.

The evidence of the geological horizon, derived from the fossils, is at present imperfect; for the animal remains found in the slates, in association with the plant-remains, are chiefly Graptolites, though fragments of *Encrinites*, species of *Orthoceras*, and some Brachiopods are occasionally found. The following species of Graptolites were recognized by Mr. Hopkinson, in a collection made by him and myself at different horizons in this quarry in 1875, viz. *Cyrtograptus Murchisoni*, *Monograptus priodon*, *M. Sedgwickii*, *M. spiralis*, *M. vomerinus*, *M. Halli*, and *Retiolites Geinitzianus**.

These forms, he considered, were "characteristic of beds at the summit of the Coniston Mudstones, or base of the Coniston Flags" in the Lake district. The abundance of Graptolites found in these beds would tend to show that the deposits, for the most part, were thrown down in a tolerably quiet sea.

It seems, therefore, so far as the evidence can be read at present, that this immediate area was not greatly affected by the physical changes which occurred in the neighbouring areas at the close of the Bala epoch—that if uplifted above sea-level, it must have been previous to the deposition of the Corwen Grits, as shown by Prof. Hughes. The physical break, therefore, if it exists here at all, must be placed at that point, and not, as formerly supposed, at the base of the so-called Tarannon Shales. There is, however, no visible unconformity between the Lower and Upper Silurians anywhere in the sections in this neighbourhood; and it is quite possible that the area may have remained under water during the whole of the Mid-Silurian epoch †. The parts raised above sea-level were chiefly to the south-east, south, and north-west of this area. I am inclined to think that there was not a very extensive land area, but numerous islands, some of them of volcanic origin. They reached undoubtedly as far as Shropshire to the S.E., and to Caernarvonshire (and probably beyond it) to the N.W. There is no satisfactory evidence to show that they extended much further to the S.W. than the neighbourhood of Builth, as the deposits apparently accumulated uninterruptedly during this time in part at least of Caermarthenshire, in Pembrokeshire, and in Cardiganshire. This is the only way in which we can account for the presence in those areas of some thousands of feet of beds between the topmost Bala and the Wenlock series, and

* Mr. C. Lapworth has also kindly examined a small collection made by me recently in the same quarry, and mentions the following forms as recognizable. They were chiefly collected from the middle bands of slate and above the beds with nodules and anthracite:—*Retiolites Geinitzianus*, *Cyrtograptus Murchisoni*, *Monograptus vomerinus*, *M. personatus*, *M. priodon* (and vars. *riccantonensis*, Lapw., and *Flemingii*, Salt.). He states, as to the correlation of these beds with those in other areas, that, so far as the evidence derived from the above Graptolites can be made out, they would occupy a position equivalent to the "lower zones of the Wenlock shale of Shropshire and the west of England."

† See paper by author, Brit. Assoc. Report, 1875.

their almost entire absence in the Longmynd and other districts. For the same reason also it must be expected that a great diversity will be shown in the sediments belonging to this period in different areas, and particularly so in proportion as they approached to or were distant from any of the raised parts. The fauna would also in consequence vary considerably. For these reasons it becomes difficult to correlate with any satisfaction all the beds which are found between the Hirnant limestone of the Bala epoch and the base of the Wenlock, which are known in different places chiefly under the name of Llandovery or May-Hill, or Tarannon, and in the area under consideration as the Denbigh Grit and Flag series. The conclusions, therefore, arrived at in regard to the plant-remains and the geological horizon in which they are found are:—that the age of the beds must be somewhere between the base of the Wenlock and the Lower Llandovery, probably not far from the horizon of the May-Hill beds (Mid Silurian); that the plants did not live on the surfaces on which they are now found; that their position here is an accidental one; that they were not brought from a great distance, as they occur at several horizons; that the shore-line from which they were derived was towards the south or west; and that the land areas were chiefly formed towards the close of the Bala epoch.

If we compare these plant-remains with those discovered in lower Palæozoic rocks in other areas in this country, we do not find so important an assemblage anywhere so low in position, certainly not at a lower horizon than the Upper Ludlow rocks, and probably not below the Devonian. It is probable also that an equal number of important plants have not been found together at so low a geological horizon in any other part of the world. Those found in the Silurian rocks elsewhere are:—the branch of a fern, described by Count Saporta under the name of *Eopteris Morieri*, discovered by Professor Morière in the Middle Silurian at Angers, France; the *Glyptodendron* of Prof. Claypole, from the Clinton group of Ohio, America; and the species of *Psilophytum*, *Annularia*, and *Sphenophyllum* described by Prof. Lesquereux, also from the Silurian rocks of Ohio. It is a curious fact that in each of these areas, in Britain, France, and America, the land plants are in a greatly broken condition, and occur in association with a marine fauna.

Their geological position in each country seems to bear out the view that physical changes were taking place almost contemporaneously in Britain, in parts of the continent of Europe, and in America at this time. These changes, which took place towards and at the close of the Lower-Silurian (Ordovician) epoch, caused land to be formed in each of these areas of greater extent than could have existed since the earliest Cambrian times; therefore it is probable that unless we find land plants in the lowest Cambrian deposits, we are not likely to meet with them in the intermediate groups, which appear to have been deposited upon each other uninterruptedly. That there were periods of shallow water, when deposits were thrown down nearly at an equal rate with the depression, is certain; and marine plants probably lived in abundance. The cellular structure of the marine plants, however, rendered them so readily liable to decomposition, that it is not much to be wondered at that their remains are seldom found. The various markings which have been attributed to land and marine plants in the earlier rocks may in some cases have been produced by them; but others, as shown by Salter, must have been tracks produced by worms. Of the most important of those about which doubt still remains may be mentioned *Eophyton* of Torell, from the Lower Cambrian rocks of Scandinavia, but which I have also found at St. David's. *Cruziana*, from the Lingula-flags of North Wales, supposed by Salter to be a worm-track, I believe, from evidence I have been collecting for some time, will prove to be an Alga. *Buthotrephis*, found in the Lingula-flags and in the Arenig rocks in Wales, and by Prof. Nicholson in the Skiddaw Slates of Cumberland*, but first discovered and described by Prof. Hall in America, appears also to be allied to the Algæ. Of *Eophyton? explanatum*, which I found in the Tremadoc rocks of St. David's, I fear the evidence is scarcely sufficient to ally it with land plants. Its strong tubular structure renders it unlike any known land plant; and the only other fossil found yet to which it can be compared is the *Pyritonema* of Prof. M'Coy, placed by him amongst the Zoophytes, though its true nature is still a matter of much doubt.

Appendix. By R. Etheridge, Esq., F.R.S., Pres. Geol. Soc.

Early in the present month Dr. Hicks brought for my inspection several slabs of micaceous sandstone, having upon their surfaces numerous fragments of carbonaceous matter, which possessed no definite shape or apparent structure. Their general appearance, in some cases, was that of decomposed coniferous wood, in others, resembling bundles of finely striated black or dark-brown carbon, brittle or tough, the black portions being by far the most brittle; the lighter and darker remains, however, undoubtedly belong to the same plant, but differently mineralized. Hitherto, in Britain, no true plant-remains are known to occur below the Upper Ludlow, and the only recognized species in that formation is *Pachytheca*, or *Pachysporangium*. Between the Upper Ludlow and the base of the Denbighshire Grits no traces whatever of plant-remains have yet occurred in British Silurian strata.

Dr. Dawson, as far back as 1859, in his paper upon the "Fossil Plants from the Devonian Rocks of Canada"†, described, amongst

* The fossils formerly placed by Prof. Nicholson in the genus *Buthotrephis*, from the Skiddaw Slates, have been since redescribed by him and Dr. Dawson under the generic name of *Protannularia*.

† Quart. Journ. Geol. Soc. vol. xv. p. 484.

other things, a new genus which he called *Prototaxites*, and the species *Logani*; he considered this to be the oldest known fossil tree in America, and, as such, gave it the name of *Prototaxites*, believing that it belonged to the Taxineæ. Subsequently (1863), in vol. xix. of our Journal, he described other fossil plants from the Gaspé Devonians; and apparently the same or a similar fossil is again described under the name of *Nematoxylon crassum*.

Specimens of this plant (*Prototaxites*) were subsequently examined by Wm. Carruthers, Esq., F.R.S., who pronounced it to be a colossal Alga, or seaweed, and named it *Nematophycus*. Mr. Carruthers published an important paper upon this plant, wherein he gives his reasons for widely differing from Dr. Dawson *.

Immediately on the receipt of Dr. Hicks's specimens, and knowing how large a problem depended upon a right interpretation of the structure and affinities of the plant-remains, through their stratigraphical position or age, I at once obtained Mr. E. T. Newton's aid in preparing microscopical sections. The result has been in the highest degree satisfactory; and he at once determined these remains from the Denbighshire Grits of Pen-y-Glog to be the *Nematophycus* of Mr. Carruthers.

Mr. Newton and myself have microscopically examined several sections of both the lighter and darker portions of the carbonaceous matter placed at our disposal by Dr. Hicks; and we feel convinced that they both present the same structure, the difference seen being almost wholly due to the fact that the intensely opaque nature of the carbonaceous matter in the darker specimens obscures the structure. Mr. Newton's observations were therefore made upon the light-coloured specimens, which we have carefully examined together. When examined with transmitted light and with a low power, the fragments show that the fibrous appearance is due to a number of dark rod-like tubes or cells running in a longitudinal direction, but in a more or less vermiform or wavy manner, sometimes closely packed together (fig. 2), sometimes more widely separated: these tubes or cells have one general direction, and consequently appear nearly parallel; but closer examination shows that other cells irregularly curve in and out of plane, and are not parallel.

In many parts a dark and apparently granular substance seems to fill the tubes, and may be resolved into round globules varying in size (fig. 3).

In certain favourable spots some of the tubes appear to be crossed by very fine transverse lines (fig. 4) which strongly resemble spiral fibres; these lines, however, may be due to the nature of the mineral which fills the cells. On others a network of fine lines may be seen spreading over the tubes; these might be thought accidental but for their frequent occurrence. In transverse section (fig. 1) the

* Trans. of the Royal Microscopical Soc., Monthly Microscopical Journal, 1872.

cells are more or less circular, and are separated by greater or less interspaces in different parts of the section.

Compared with the *Nematophycus Logani* as figured by Mr. Carruthers, the minute structure of these carbonaceous fragments will be found to agree precisely, with the one exception that the finer tubes or cells filling the interspaces between the larger ones, which Mr. Carruthers figures and describes in *Nematophycus*, are not so distinct in Dr. Hicks's specimens. The double spiral fibres figured by Dr. Dawson when he first described his *Prototaxites* (=*Nematophycus*, Carr.), are rather to be referred to the interlacing cells (network in Pen-y-Glog specimens) than to the fine spiral fibres seen in the latter (fig. 4).

The rounded seed-like bodies found with the carbonaceous fragments are hollow and thick-walled. In microscopical sections the wall is found to be composed of radiating fibres (cells ?) arranged nearly parallel to each other and slightly wavy (fig. 8). These cells are irregularly filled with spore-like bodies. The seed-like bodies resemble the *Pachytheca* from the Upper Ludlow beds both in their outward form and in the radiated structure of their walls.

The question naturally arises, Are the carbonaceous fragments so well known to occur in the Ludlow bed (Downton sandstone) of the same nature and structure as the Denbigshire-grit specimens? Mr. Newton has not been able to obtain transparent sections of the Ludlow woody specimens; but, from what little we have been able to make out, these Ludlow fragments likewise show tubular structure, but not quite of the same character as those from Pen-y-Glog.

On first seeing Dr. Hicks's specimens I pronounced the remains to be those of some marine Alga; but I was not then acquainted either with Mr. Carruthers's paper on *Nematophycus* or Dr. Dawson's description of *Prototaxites*, neither being then known as British plants; and no opportunity had occurred to me for examination. The sections made by Mr. Newton reveal in the most perfect and satisfactory manner the innumerable vermicular cellular filaments which constitute nearly the entire structure of what must have been the stem, and also the dense spongy nature produced by the smaller tubes, which seem to ramify irregularly. The larger tubes are not strictly parallel to each other, although they run in the same general direction; they appear to be continuous, and their ends bluntly rounded.

The description of the structure of *Nematophycus*, and the discussion of its affinities with certain orders in the Chlorospermeæ, are so ably and completely done by Mr. Carruthers, that little is left for further description, especially as there is no doubt whatever that the plant-remains in the Denbighshire Grit from Pen-y-Glog are unquestionably *Nematophycus* of Carruthers, and the *Prototaxites* and *Nematoxylon* of Dr. Dawson, referred by Dr. Dawson to the Coniferæ through the Taxineæ or Yews.

The fragments, small as they are, show unmistakably that we have at this low horizon the Gaspé plant (*Prototaxites*) which occurs in the Devonian rocks of America. This is an important fact, as the so-called Fucoidal remains are mere impressions, and many, if not all, are trails or burrows of Annelida.

The interest at first attached to these special remains was centred in the hope that they were portions of terrestrial vegetation growing on a contiguous land surface during the deposition of the Denbighshire Grits. Now, however, we have clear evidence that these remains, to which we more especially refer, formed portions of a colossal seaweed whose habit resembled that of the North-Pacific species of the genus *Nereocystis* and the arborescent *Lessoniæ*, and probably, as Mr. Carruthers suggests, the *Macrocystis pyrifera*, which attains the length of 700 feet. The arborescent *Lessoniæ*, belonging to the natural order Laminariaceæ, form large submarine forests, the stems of which, when dry, *resemble* exogenous wood, owing to a false exogenous growth. This pseudo-exogenous structure is well known in many of the Algæ. Mr. Carruthers suggests that in the arborescent *Lessoniæ* we have a near approach to the Devonian *Nematophycus* or *Prototaxites*. Many of the stems in *Lessonia* measure a foot in diameter and 30 feet in length. The *Laminariæ* of our own shores exhibit a pseudo-exogenous growth; but, as is well known, the difference in growth between the Antarctic *Lessonia* and the genus *Laminaria* consists in the "exogenous increase in *Laminaria* being from *below upwards*, according to the growth of *the roots*, while in the genus *Lessonia* the growth is from *above* downwards, in proportion to the increase of the leaves"*. *Macrocystis* belongs to the same natural order (Laminariaceæ), but possesses a different habit. I may mention also *D'Urvillea Harveyi*, Hook., another of the Laminariaceæ, which possesses a stem-structure most closely resembling *Nematophycus* in the vermiform nature of the cells or tubes, and their irregular semiparallel arrangement. Dr. Hooker describes and figures this plant in his 'Antarctic Voyage,' vol. ii. t. 165–6 (fig. 2); a figure of the longitudinal structure of the stem is given on the plate. The Corwen *Nematophycus* is converted into amorphous silex. This condition interferes with the microscopic structure being readily made out, giving apparently false lines across the tubes or cells; and whether the spiral fibres are inside or outside the large tubes, or independent structures outside, I am unable to say; neither can Mr. Newton or myself clearly make out that the so-called spiral fibres or concentric lines upon the tubes can be resolved into minute dots. His figure (fig. 4) is most carefully drawn; and one of the tubes containing the globular bodies is also delicately and similarly lined. Fresh observations may enable us to determine whether the spiral lines can be resolved into dots or not. The longitudinal and transverse sections prepared by Mr. Newton show every feature described by Mr. Carruthers in his paper. The elongated cylindrical cells, of two sizes, appear completely and irregularly interwoven, as Mr. Carruthers well expresses it, into a kind of

* Berkeley's Introduction to Cryptogamic Botany, p. 57; Carruthers, Monthly Microscopical Journal, 1872, pp. 170, 171.

felted mass; and in the figure of the longitudinal structure of the stem in *D'Urvillea Harveyi* given by Dr. Hooker (*loc. cit.*) an irregular vermiform interlacing and interweaving of the cells or tubes is shown, remarkably agreeing with the structure of *Nematophycus*. It would be interesting to ascertain if the large round spore-like bodies (which are here termed *Pachytheca* or *Pachysporangium*, fig. 7) are the sporangia of *Nematophycus*: the cells which radiate from the central cavity are certainly filled with round spore-like bodies arranged in single file, or disposed in such a manner as to be shed from the periphery or circumference of the body called *Pachytheca*. This is manifest in the structure of one of these cut through and shown under the microscope (fig. 9). The large tubes or cells, constituting the stem structure, which appear here and there to contain round spore-like bodies similar to these, do not really do so; they are, I believe, accidentally scattered here and there, and *appear* to be within rather than upon the tubes in the microscopic sections.

On two of Dr. Hicks's rock specimens there are singular honeycomb-celled bodies having all the appearance of being coriaceous or membranous capsular bodies, or sporangia; the outer portion was definitely composed of either four- or six-sided cells. This sac-like body may have played some part in the history of *Nematophycus*. Under any circumstances they are worthy of notice, and are undoubtedly organic.

The plant called *Prototaxites* by Dr. Dawson, from the Gaspé beds, of Devonian age, was one of the oldest plants then known; the previously known oldest plants are mere fragments of woody matter: these occur with *Pachytheca* in the Upper Ludlow, of the Ludlow area; and no older British rocks have, until now, yielded any. Looking at the probable distribution of a marine flora the plants composing which were of such magnitude and probably widely spread over the Devonian sea-bed, we naturally turn to the origin or source of the Gaspé Devonian species. The presence of *Nematophycus* in the Denbighshire Grits is proved by these researches of Dr. Hicks; but no remains of a similar kind have been found through the higher beds of the Woolhope, Wenlock, and Ludlow rocks—except at the close of the Ludlow, in the Downton shales, if the seed-like bodies termed *Pachysporangium* or *Pachytheca* are to be regarded as portions of *Nematophycus*. If they have no relation to each other, then we have to account for the wide distribution in time of both—*Nematophycus* from the Denbighshire Grits to the Devonian, and *Pachytheca* from the Denbighshire Grits to the Upper Ludlow. We are warranted, I think, in believing that there is far less chance of these being one species than modified descendants from an older stock, the entire area never having been dry land at one time since the deposition of the Denbighshire Grits; I therefore give this the specific name *Nematophycus Hicksii*. I look forward to finding the remains of this group of Algæ in rocks of far higher antiquity; for it is evident that marine plants of such colossal size as the Gaspé species is known to have been could not then have made their first appearance. Again, the habitat of *Nematophycus*, if it at all resembled the present *Lessoniæ* in growth at the bottom of the ocean, may have survived many changes between land and sea during the deposition of the Upper Silurian rocks, while yet the sea-bottom or bed of the Silurian Sea was never exposed or became dry land. The finding and determining the nature of these remains opens up a great problem, so far as the age, continuity, and distribution of Cryptogamic life in palæozoic time is concerned.

EXPLANATION OF PLATE XXV.

Fig. 1. *Nematophycus Hicksii*: cross section, × 200.
2. Ditto: longitudinal section, × 200.
3. Ditto: tubes filled apparently with granular substance, × 325.
4. Ditto: tubes covered by fine transverse lines, × 325.
5. Ditto: portion of stem, natural size.
6. Ditto: fragments, ditto.
7. *Pachytheca*: × 6.
8. Ditto: portion of wall, × 200.
9. Ditto: fibre in wall, × 200.
10. Microspores, probably of a Lycopodiaceous plant, × 15.

Discussion.

Mr. Carruthers spoke of the importance of Dr. Hicks's discovery, and said that after the President's note it was needless for him to add much. He had come in the main to the same conclusion. The view of the significance of the *Pachythecæ* was interesting; but the data which had come before himself hardly warranted his regarding them as Algæ. He explained the reasons why he was unable to accept the President's view, and agreed with that of Sir Joseph Hooker—namely, regarding them as Lycopodiaceous. He thought also that the signs of a vascular axis in some of the specimens proved a land-flora; also there were some spores, not sporangia, which bore out this view.

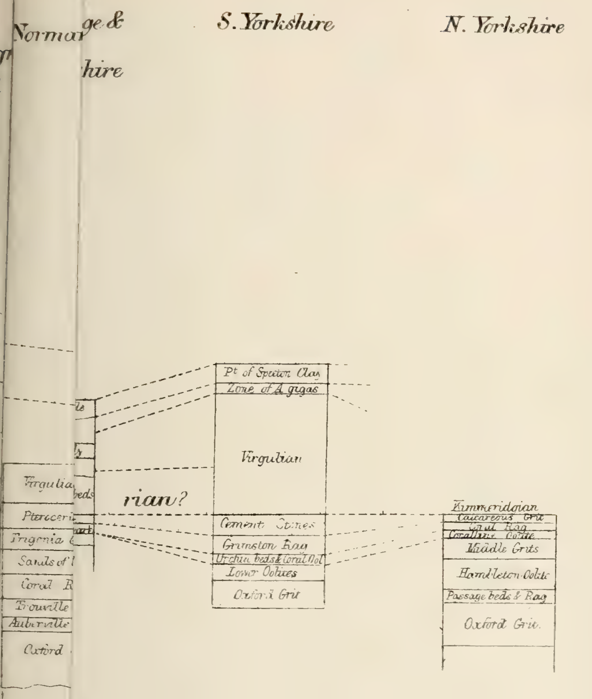
Mr. Hopkinson said that the Graptolites were partly Middle Silurian and partly Upper Silurian forms, some being Llandovery species, here dying out, and others Wenlock species, first appearing here. The change in type seemed to imply an alteration in physical conditions.

Mr. De Rance referred to some Ludlow pebbles at the base of the Carboniferous, and said that anthracite occurred in beds of the Lake-district of about the same age.

Prof. Duncan spoke of the good fortune which had attended Dr. Hicks's investigations in unpromising ground. The cellular plant discovered by him was a very remarkable one; it reminded him of *Codium*. The undulated underpart of the cellulur structure was very remarkable, indicating a general rugosity or a spiral fibre; that fibre occurred in modern water-plants. In one part there was something like a dissepiment. As in the beds above the Gannister, there might be a common link here of land- and water-plants. He commented on *Pachytheca*, and asked whether it could have any relation to the floats in the *Sargassum*. These old plants seemed capable of existing under conditions very similar to the present.

Mr. TAWNEY said he thought a *Lepidodendron* had been found in the Silurians of America.

Dr. HICKS said that Saporta had described a species from about the same horizon, supposed to be a mineralized fern. He thought that here was an admixture of land- and marine plants, and believed much more would be found. At present *Nematophycus* was the best preserved.



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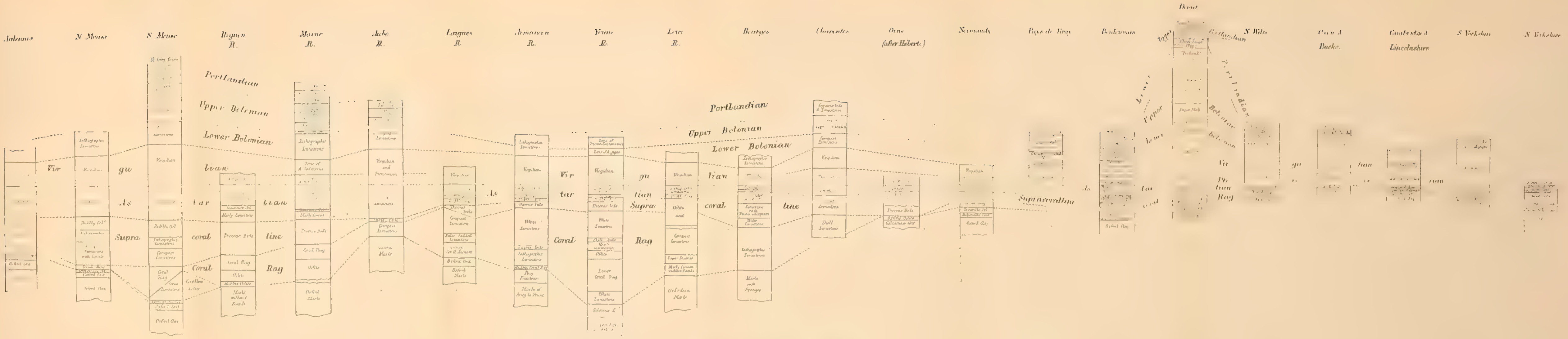

COMPARATIVE SECTIONS OF UPPER JURASSIC ROCKS, PARIS BASIN AND ENGLAND.

38. *On the* Correlation *of the* Upper Jurassic Rocks *of* England *with those of the* Continent.—Part I. The Paris Basin. By the Rev. J. F. Blake, M.A., F.G.S. (Read April 27, 1881.)

[Plate XXVI.]

In former papers on the Portland Rocks*, the Kimmeridge Clay†, and the Corallian Rocks‡, as developed in our own country, it has been pointed out that, while the normal deposits of the period commencing with the Oxford Clay and continuing to the close of the Jurassic era were essentially argillaceous, the uniformity has been broken by certain episodes which have resulted in the formation of distinct kinds of rocks, but that, in spite of these episodes, there is a continuousness both in the physical and biological features, uniting the whole into one great group, to which the term *Upper Jurassic* is appropriated. The present study ought therefore, logically, to include a correlation of the Oxford-Clay series; but though the upper portions of that series come to be incidentally examined, the far wider range and greater constancy of the lower portion would render its examination a more arduous and less interesting task; and it is found convenient to have for base a thick mass of clay, which may almost everywhere be recognized, however much the upper part may be encroached upon lithologically by the various preludes to the Corallian series. In point of fact, the rocks hitherto called Corallian in England comprise much that is placed in the Oxfordian by the French geologists; and our correlation is therefore only stopped when the rocks universally called Oxfordian are reached.

The Upper Jurassic rocks of France lie in two distinct areas. The more northern is that which is drained by the Seine and the Loire and smaller rivers having a similar direction; the more southern is a continuation of the Swiss Jura, or lies to the south of the central plateau of Auvergne. The former constitutes the basin of Paris, round which city the Jurassic rocks form an irregular curve; and their development in this range forms the subject of the present study, the Upper Jurassic rocks of other districts being left for a future occasion.

Much good work has been done by the French geologists in the description of the various portions into which this basin may be divided, and in the correlation of the rocks with one another, by the aid of which it is possible for a foreigner to pass from spot to spot, appreciating, confirming, or even correcting the stratigraphical succession and its interpretation. The advantage that such a student has is that, instead of being confined to one area, and being obliged to obtain his ideas from it, he can make the several

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 189.
† *Op. cit.* vol. xxxi. p. 196.
‡ *Op. cit.* vol. xxxiii. p. 260.

areas mutually throw light on each other, and present a complete idea of the whole and not merely of isolated fragments. Oppel, in his work 'Der Juraformation,' made such a comparative study in 1860; and Hébert, in his pamphlet 'Les Mers Anciennes,' did the same for the basin of Paris in 1857. Since those dates much new material has accumulated; and it is possible also to bring English rocks into the comparison. Hence several fresh questions have arisen, and divergences of interpretation have been developed, on which it is impossible to come to any conclusion without a uniform and comprehensive study in the localities themselves, which will usually show that nature is much more simple than her various interpreters between them would make her.

The following numbered list gives some account of what has been written on the Upper Jurassic rocks of the Paris Basin:—

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(3) 1844. Raulin. Mémoire sur la constitution géologique du Sancerrois. Bull. Soc. Géol. Fr. ser. 2, vol. ii. p. 84.
(4) 1844. Royer. Note sur les terrains jurassiques supérieurs et moyens de la Haute Marne. Bull. Soc. Géol. Fr. ser. 2, vol. ii. p. 705.
(5) 1844. Royer. Comparaison des terrains jurassiques de l'Yonne avec ceux de la Haute Marne. Bull Soc. Géol. Fr. ser. 2, vol. ii. p. 714.
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(7) 1846. Leymerie. Statistique du département de l'Aube.
(8) 1847. Graves. Essai sur la topographie géognostique du département de l'Oise.
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(17) 1855. Manès. Statistique géologique de la Charente Inférieure.
(18) 1856. Cotteau. Compte Rendu de la session tenue par la Société Géologique de France le 7 Septembre à Joinville (Haute Marne).—Comparaison des terrains observés par la Société avex ceux du département de l'Yonne. Bull. Soc. Sc. Hist. et Nat. Yonne.
(19) 1856. Réunion Extraordinaire de la Société Géol. de France à Joinville. Bull. Soc. Géol. Fr. ser. 2, vol. xiii. p. 787 (*Royer*).
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(22) 1857. Buvignier. Observations sur le terrain jurassique de la partie orientale du bassin de Paris. Bull. Soc. Géol. Fr. ser. 2, vol. xiv. p. 595.
(23) 1858. Coquand. Description géologique de l'étage Purbeckien dans les deux Charentes. Bull. Soc. Géol. Fr. ser. 2, vol. xv. p. 577.
(24) 1858. Coquand. Statistique de la Charente.
(25) 1858. Leymerie & Raulin. Statistique géologique du département de l'Yonne.
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(32) 1864. Ebray. Etudes Paléontologiques sur le département de la Nièvre.
(33) 1865. Rigaux. Notice stratigraphique sur le Bas-Boulonnais. Bull. Soc. Acad. Boulogne.
(34) 1865. Cotteau. Deux jours d'excursion dans le terrain jurassique des environs de Tonnerre (Yonne). Bull. Soc. Sc. Hist. et Nat. Yonne, 1865.
(35) 1865. Waagen. Versuch einer allgemeinen Classification der Schichten des oberen Jura.
(36) 1866. Pellat. Notes sur les assises supérieures du terrain jurassique de Boulogne-sur-Mer, &c. Bull. Soc. Géol. Fr. ser. 2, vol. xxiii. p. 193.
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(39) 1866. De Loriol & Pellat. Monographie paléontologique et géologique de l'étage Portlandien des environs de Boulogne-sur-Mer. Mém. Soc. Phys. Genève, tom. xix.
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(43) 1868. Cotteau. Nouvelles observations sur le terrain jurassique des environs de Tonnerre. Bull. Soc. Sc. Hist. et Nat. Yonne. ser. 2, tom. ii.
(44) 1868. Tombeck. Note sur le terrain Portlandien de la Haute Marne. Bull. Soc. Géol. Fr. ser. 2, vol. xxv. p. 456.
(45) 1868. Tombeck. Note sur les terrains Corallien et Kimmeridien de la Haute Marne. Bull. Soc. Géol. Fr. ser. 2, vol. xxv. p. 458.
(46) 1870. Pellat. Sur l'étage Portlandien du Pays de Bray. Bull. Soc. Géol. Fr. ser. 2, vol. xxvii. p. 683.
(47) 1870. Pellat. Nouvelles observations sur quelques assises du terrain jurassique supérieur du Boulonnais. Bull. Soc. Géol. Fr. ser. 2, vol. xxvii. p. 683.
(48) 1870. Tombeck. Sur les étages jurassiques supérieurs de la Haute Marne. Bull. Soc. Géol. Fr. ser. 2, vol. xxvii. p. 687.
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(55) 1873. Tombeck. Note sur l'Oxfordien et le Corallien de la Haute Marne. Bull. Soc. Géol. Fr. ser. 3, vol. i. p. 335.
(56) 1874. De Loriol & Pellat. Monographie Paléontologique et Géologique des étages supérieurs de la formation jurassique des environs de Boulogne-sur-Mer. Part i. Mém. Soc. Phys. Genève, tom. xxiii. p. 253.
(57) 1874. Tombeck. Note sur l'Oxfordien et le Corallien de la Haute Marne. Bull. Soc. Géol. Fr. ser. 3, vol. ii. p. 14.
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(59) 1874. Bayan. Sur la succession des assises et des faunes dans les terrains jurassiques supérieurs. Bull. Soc. Géol. Fr. ser. 3, vol. ii. p. 316. Followed by observations by *Tombeck* and *Pellat*. *Ibid.* p. 343.
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(61) 1876. De Loriol & Pellat. Monographie, &c. des ét. sup. jur. de Boulogne. Part ii. Mém. Soc. Phys. Genève, tom. xxiv. p. 1.
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(63) 1876. Tribolet. Sur les terrains jurassiques supérieurs de la Haute Marne comparés à ceux du Jura suisse et français. Bull. Soc. Géol. Fr. ser. 3, vol. iv. p. 259.
(64) 1876. Tombeck. Note sur le Corallien et l'Argovien de la Haute Marne. Bull. Soc. Géol. Fr. ser. 3, vol. iv. p. 162.
(65) 1877. Tombeck. Corallien de la Haute Marne. Bull. Soc. Géol. Fr. ser. 3, vol. v. p. 24.
(66) 1878. Tombeck. Sur la position vraie de la zone à *Ammonites tenuilobatus* dans la Haute Marne et ailleurs. Bull. Soc. Géol. Fr. ser. 3, vol. vi. p. 6.
(67) 1878. Struckmann. Der obere Jura der Umgegend von Hannover.
(68) 1878. Pellat. Résumé d'une description du terrain jurassique supérieur du Bas Boulonnais, &c.
(69) 1879. De Lapparent. Le Pays de Bray.
(70) 1879. Tombeck. Réponse aux observations de M. Buvignier. Bull. Soc. Géol. Fr. ser. 3, vol. vi. p. 310.

On studying these writings it soon becomes obvious not only that questions of theory are in dispute, but that facts are variously stated also, and that the latter must first be settled before the former can have a solid foundation. The study therefore becomes divided into two parts:—first, observations made for the verification or modification of the accounts of the true sequence in the various areas; and, secondly, discussion of the opinions expressed on the relations and groupings of the rocks, with special reference to the equivalents in our own country.

Within the area here spoken of as the Paris Basin there are five ranges, of very unequal size and importance, separated from each other by intervals in which older or newer rocks occupy the surface of the ground. These are

I. From the Ardennes to the Cher.
II. The two Charentes.
III. Normandy, with Orne and Sarthe.
IV. The Pays de Bray.
V. The Boulonnais.

The first-named district, though not the nearest to England, nor presenting characters most similar to those of our own country, yet, from its large size, the continuousness of its deposits and the labour that has been bestowed upon them, presents itself as the most typical for France, and the one therefore to be studied first, so that we may better understand the last three, which in some sense are intermediate between the French and English types.

I. From the Ardennes to the Cher.

Although this range has been studied continuously from one end to the other, it is necessary in description to subdivide it into those smaller areas which have been made the subjects of special monographs by French geologists.

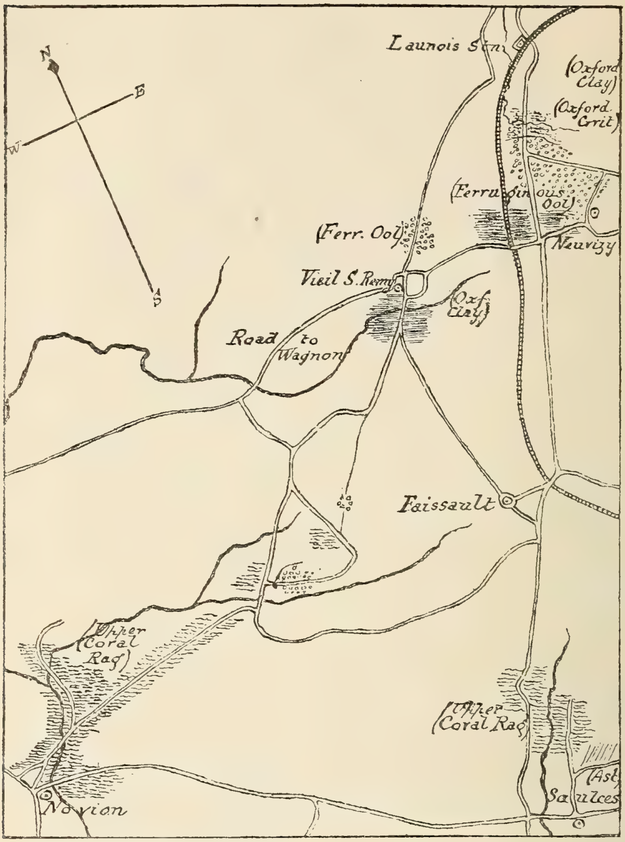
1. *The Ardennes Department.*—The rocks of this area have received illustration at the hands of MM. Sauvage and Buvignier (2)*, who give the following classification

1. Upper Group.
    - *a.* Marls with *Exogyra virgula*, 160 ft.
    - *b.* Calcaire à Astartes, 21 ft.
2. Coral Rag, 250 ft.
3. Oxfordian.
    - *a.* Ferruginous oolite, 28 ft.
    - *b.* Marls and limestones, 300 ft.
        - (1) Shelly siliceous limestone, (2) marls, (3) ironstone.
    - *c.* Lower marls with ironstone, 30 ft.

Commencing this series from the base, 3 *c* may be passed over as Callovian, while 3 *b* (2) and (3), forming the great mass of the 300 ft. and occupying the valleys, will represent the undoubted Oxford Clay. The series 3 *b* (1) then commences the group of rocks now under study. If for "siliceous limestone" we read its equivalent, "calcareous grit," we have the term which will exactly suit the English geologist, who at once recognizes in it a representative of his 'Lower Calcareous Grit.' At the base, as seen in quarries on the road from the station of Launois to Neuvizy, is hard blue calc-grit; and above this, nodular beds of grit in a subargillaceous matrix. Some of these are very light, like the Upper Calcareous Grit of Yorkshire, and are said by Sauvage and Buvignier to be soluble in potash, indicating a possible organic origin, like the *Renulina*-grits of Scarborough; the fossils, however, are in some cases 'beekized.' These nodular beds, which begin to present some of that peculiar feature indicated

* See list of works above.

Fig. 1.—*Map of Country near Neuvizy.* (Scale 1 : 80,000.)



by the term ‘terrain à chailles’*, contain a characteristic fauna, viz. *Ammonites cordatus, Modiola bipartita, Perna quadrata, Pecten fibrosus, Avicula expansa, Exogyra spiralis, Ostrea dilatata, O. rastellaris Rhynchonella Thurmanni*, and several others less certainly identified, but all indicating a horizon similar to that of the Nothe grits and clays or of the Lower Calcareous Grit of Yorkshire. At the top this series becomes much more calcareous, and finally contains abundant oolitic grains, while a change of fauna takes place. This has been very imperfectly examined; but the three chief species are *Ammo-*

* This term "terrain à chailles" is a misleading one. It is often used as if indicating a fixed horizon; but it appears from French writers that there is one of these ‘terrains’ in the Callovian, another in the Oxfordian (the present one), and a third in the Corallian; so that it is really a mere petrological phrase similar to "nodular beds".

nites oculatus of the variety called *A. Bachianus*, Oppel, *Trigonia spinifera*, d'Orb. (Prodr.), and *Rhynchonella Thurmanni*. The *Trigonia* is specially noticeable: it has been found by Mr. Hudleston at Snainton in Yorkshire, in a quarry belonging to the passage beds above the Lower Calcareous Grit, and named by Dr. Lycett *T. snaintonensis*; but, though never figured by the French geologists, it seems to be abundant in the Ardennes department, and occurs on the same horizon in the Vosges. The Ammonite serves to show how essentially Oxfordian these beds still are. Their total thickness is about 50 feet.

Next in the series is the Ferruginous Oolite, which, from its easily recognized mineral character and its rich fauna, has attracted considerable attention, and has been constantly used by authors as a term of comparison for beds in other districts. It is of no great thickness, 28 feet being given as its maximum. At Vieil-St.-Remy it is an earthy limestone with scattered oolitic grains of limonite and crowded with fossils.

At Neuvizy almost every thing but the oolite grains has been dissolved, and these remain as a loose deposit containing 'beekized' fossils with vacuous interiors. The latter character, however, is exceptional, as the bed may be traced in the former character as far south as Commercy, if not further, a distance of 100 miles. It is, in fact, remarkable for its constancy, especially as compared with the beds above it; and if a division is to be made in the series in this district on stratigraphical grounds, it is certainly over this that the line must be drawn. From this rock more than 200 species have been recorded in this department, and 190 in the department of the Meuse. In such a fauna one naturally finds representatives of species which are abundant on several horizons; and one may therefore easily be misled to place it on any horizon that one happens to be most familiar with. Two Ammonites are common, viz. *A. cordatus* and *A. Martelli*, the latter being the *A. plicatilis* of d'Orbigny. A form which may belong to the true *A. plicatilis* occurs in the same beds in the Meuse department; and d'Orbigny and Buvignier both quote *A. perarmatus* from this horizon as well as from the beds below. Amongst the Gasteropoda quoted from here, *Cerithium muricatum*, *Littorina muricata*, *Pseudomelania striata*, *Chemnitzia heddingtonensis* and *Bulla elongata* are constantly met with in the lower Corallian limestones in England, the *Pseudomelania* being more characteristic of higher beds. Amongst the Lamellibranchiata, *Gryphæa gigantea*, *Pecten fibrosus*, *Lima gibbosa*, *Gervillia aviculoides*, *Avicula expansa*, *A. ovalis*, *A. polyodonta* (the same as our *A. pteropernoides*), *Perna quadrata*, *Mytilus pectinatus*, *Cucullæa oblonga*, *Opis similis*, *Astarte extensa*, *Tancredia curtansata*, *Isodonta Deshayesia*, *Myacites decurtatus*, and *Pholadomya ovalis* are most noticeable as confirming the evidence of the Gasteropoda; but *Pecten vimineus* points to a rather higher horizon; while the presence of *Rhynchonella Thurmanni*, and of what is probably *R. lacunosa*, with abundance of *Waldheimia bucculenta* and *Terebratula fileyensis*, is still in harmony; and finally the echinoderms *Millericrinus echinatus*, *Echinobrissus scutatus*, *Holectypus depressus*, and *Collyrites bicordatus* add their testimony to the great similarity which the fauna of this ironstone bears to the lower portions especially of the calcareous series of our Corallian rocks.

This Ferruginous Oolite is referred by Hébert (21) to the middle Oxfordian on the ground that above it at Vieil-St.-Remy occurs a great thickness, 160 feet, of brown marls with a thoroughly Oxfordian fauna, such as *Ammonites arduennensis*, *Trigonia perlata*, *Gervillia aviculoides*, *Ostrea dilatata*, &c. The occurrence of any such marls is denied by Buvigner (22) who states that the Oolite seen below must be out of place. Certainly no such thickness of marl was observed where the beds were examined. About 40 feet of marls are seen at the base of the valley near Vieil-St.-Remy and in the railway-cutting near Neuvizy; but these, from their position, are more probably below the Ferruginous Oolite, which is seen too near to the Corallian limestones on the road between Vieil-St.-Remy and Novion to allow of any intervening clay of more than a few feet thickness. It is probable therefore that the Grit and Ferruginous Oolite are hidden on the road to Wagnon in the 160 feet, the base of which contains the above fossils, while over it come the marly limestones recorded to contain *Cidaris florigemma* and *Pecten articulatus*. In many other places further south also some representative of the Coral Rag is found immediately overlying the Ferruginous Oolite; so that its position is, in reality, perfectly fixed.

The constancy of this bed in spite of its thinness is in striking contrast with the variability of the succeeding series on the horizon of the *Trigonia*-beds of Pickering or of the earliest limestones of the Corallian series, which are said by Buvignier to have nothing constant but their inconstancy.

In the neighbourhood of Vieil-St.-Remy and Neuvizy the lowest beds referred to the Coral Rag are not well seen, though Hébert (21) describes about 4 feet to 5 feet of coral material with *Cidaris florigemma* on the road to Wagnon. Nowhere here, however, is there any great thickness of such growth; and what there is is succeeded immediately by the white limestone which is seen so well at the quarries of Novion. This limestone has been much acted on by chemical agents, many of the fossils being silicified and others represented only by casts. Among the latter the corals are of the greatest importance; the majority are not Thamnastræan but Calamophyllian and Cladophyllian. MM. Sauvage and Buvignier simply place the whole of these limestones, amounting, according to their estimate, to 250 feet, as Coral Rag, without further subdivision, and supply a rather defective list of fossils. At Novion a magnificent section, 100 feet in thickness, is seen, the *Calamophylliæ* in places almost forming a reef at the base; then follow great false-bedded masses of fine white limestone, and towards the top huge crystalline nodules of *Thamnastrææ*. Lithologically therefore this might well pass as a Coral Rag; and it represents in this area all that would naturally be called Corallian. When, however, we examine it more closely, we note in the first place that this is scarcely a Thamnastræan reef, such as is usual in our true English Coral Rag, the specimens at the top not being *in situ*—and also that there is an apparent absence or great rarity of *Cidaris florigemma*, the spines which occur being either smooth or belonging to *C. Smithii*. At the base the most abundant fossil is a large *Natica* like *N. millepunctata*, Buv., but perhaps *N. grandis*; while the topmost beds are crowded with silicified *Nerinææ*, *N. sequana* bring the most abundant. Other noteworthy fossils are rarer examples of *Diceras arietinum*?, *Cardium corallinum*, *Cerithium limæforme*, *Pteroceras oceani* (undistinguishable from those at Boulogne), *Lima æquilatera*, Buv., and *L. ornata*, the *Modiola imbricata*, Röm. (non Sow.), and *Terebratula*. MM. Sauvage and Buvignier mention also among others *Arca pectinata*, *Pecten articulatus*, and *Chemnitzia heddingtonensis*. These characters taken together appear to indicate a higher horizon than the '*florigemma*' Rag, namely one which in spite of its abundant corals should be paralleled with Supracoralline beds elsewhere, or the upper part of the Corallian series when that has been divided as it has been in the Meuse. The upward succession is not well seen in this neighbourhood, the great limestones passing to large-grained oolites with undistinguishable fossils, and then to more compact limestones referred to the Astartian.

The interpretation of the rocks seen in this district may now be checked by an examination of the country about 20 miles distant to the south. Starting from the town of Beaumont, and going westward, after passing over the Lower Oolites, the Kelloway Rock and the Oxford Clay, which is here well developed in an argillaceous form, one comes, at the base of the escarpment of Stonne, to the same sandy nodular beds with *Rhynchonella Thurmanni* and *Perna quadrata* as at Neuvizy, duly followed on the top of the hill by the Ferruginous Oolite; but the bed with *Trigonia spinifera* was not observed. Above this, on the road to Ochsee, a village three miles south, the succession is perfectly observable on the rough cart-road mounting a barren hill; at the base are the Lower Calcareous Grit and the Ferruginous Oolite; near the summit are the great cavitary limestones of Novion, where the *Calamophylliæ* have been, and above them flaggy Oolites &c. full of *Nerinææ*; but in the intervening space there is no sign of clay, all is calcareous. This portion, however, contains abundant Thamnastræan corals; and with them *Cidaris florigemma* was easily found associated with *Hemicidaris crenularis*, *Cerithium muricatum*, and *Littorina muricata*; but the *Nerinææ* and *Naticæ* of the limestone above are absent. It thus appears that we are justified in regarding the Novion limestone as Supracoralline; while all that can represent the series so well developed in England between the Lower and the Upper Calcareous Grit is the Ferruginous Oolite and the Rag Limestone. The upper portions of the series have not been examined in the Ardennes department, as the description given by the before-named authors indicated that they were similar to those to be seen in the northern part of the Meuse.

2. *The Meuse Department.*—On entering this we come under the guidance of Buvignier alone (13), whose classical work is well known. He gives the following classification.

1. Upper Jurassic.

I. Barrois limestone, 600 feet.

a. Grey-green limestone.
b. Carious limestones.
c. Lithographic limestones.

II. Virgulian clays, 150 feet.

III. Astartian limestones, 400 feet.

a. Upper compact limestones.
b. Lower marls.

2. Middle Jurassic.

I. Coral Rag, 400 feet.

a. Lithographic limestones.
b. Various forms.

II. Oxford clay, 500 feet.

a. Ferruginous oolite.
b. Siliceous limestones=Terrain à chailles.
c. Woèvre clay.

Near the northern extremity of the department, in the neighbourhood of Dun, the lower portions of the series may be easily taken up again; and they show a continuance of the conditions last noted in the Ardennes. On the slopes of the Côte St. Germain a fairly complete section may be seen: the lower half is occupied by the Oxford Clay, with the topmost part of the same nodular gritty character as before; then may be seen the Ferruginous Oolite, of some thickness; immediately over which come great crystalline irregular masses which, in spite of their present state, are easily recognized as remains of a Thamnastræan reef, with which *Cidaris florigemma* occurs; this portion is also considerably oolitic, differing in this respect from the limestone that follows it, which, with its vacuous spaces once filled with corals and *Nerinœæ*, perfectly represents the Novion stone. Here, then, we find confirmation of previous sections. Hébert (21) states that the Coral Rag alone is seen at the base of this hillside, and that the Ferruginous Oolite must be some distance below, and separated by a great mass of clay. The sequence, however, is here perfectly clear; and on the opposite side of the valley, in the hill between Murvaux and Fontaines, the same succession is equally well seen. Only at this spot the true Coral Rag has greatly developed, as may be seen also by its examination in other places in the neighbourhood. Thus the great quarries to the south of Dun show perhaps as much as 60 feet, consisting of a lumachelle of broken shells at the base, a Thamnastræan reef with *Ostrea solitaria* in the middle, and oolite beds with *Cidaris florigemma* at the top, all of which must be about on this horizon, and which give an idea of the variability of the series; while in the valley leading to Fontaines the still coral-bearing upper limestones are largely developed, but without the characteristic urchin of the lower reefs and their equivalents.

Passing next to Verdun, the student who has traced the lower

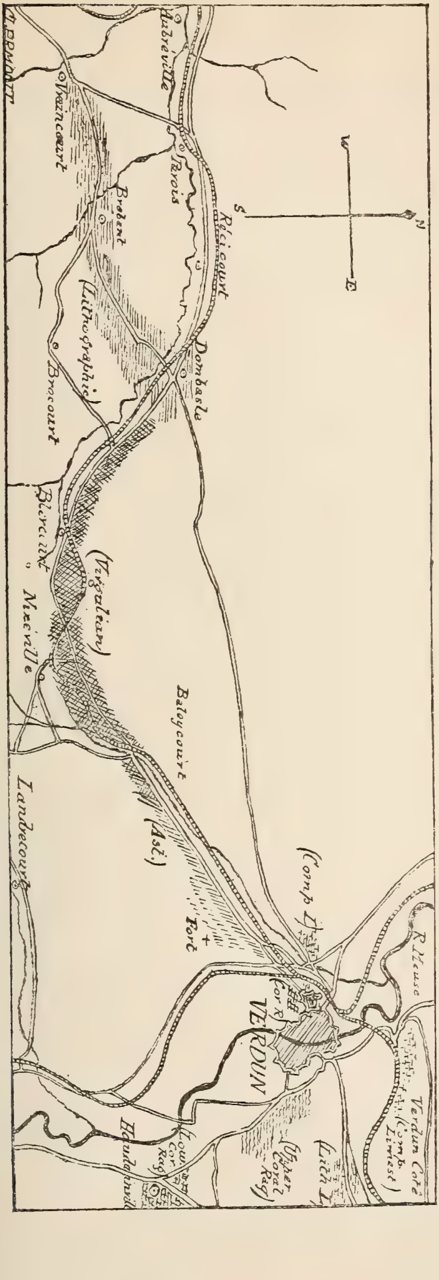


Fig. 2.—Map of the Country round Verdun. (Scale 1 : 160,000.)

rocks so far has no difficulty in assigning to their true place the magnificent limestones which here astonish him and give him an idea of the grandeur of the development of the Corallian rocks in this district. The beds which in this locality overlie the Ferruginous Oolite are altogether different from any thing seen before, consisting at Haudainville of an unstratified mass of limestone 40 feet in thickness, made almost entirely of fragments of crinoids united by a calcareous cement and yet distinct, forming a most admirable freestone: the only fossils seen in it are *Cidaris florigemma* and small oysters. Capping this mass in the quarry is 10 or 12 feet of Thamnastræan Rag with occasional *Cladophylliæ*, but with abundance of *Cidaris florigemma*, *Terebratula maltonensis*, and *Pecten vimineus*, also *Lima læviuscula* and *Venerupis corallensis*. The position, then, in this locality of the crinoid limestone is fixed; for it must be associated with the Rag above it, as forming part of Buvignier's Coral Rag *b*. The succeeding rocks, representing the Novion limestones, also introduce new features; for here is first seen the lithographic stone which becomes so abundant further west. It is mixed with Oolites of various-sized grains; but the corals of all kinds are gone. The appearance of this group in the great quarries of St. Martin has been admirably described by Buvignier—its cherty bands, its vegetable remains towards the base, and crustaceans above. The fossils are only abundant in parts; the commonest is *Nerinæa elongata*, associated with others, as *N. Jollyana* and *Patella elegans*; *Natica globosa* and *Lucina mosensis* were also collected. The upper part of this group is instructively seen on the north of Verdun, in the Côte St. Michel. The eastern portion is worked in pure lithographic limestone without a fossil; but the western shows great quarries of massive earthy limestones in which the characteristic fossil is *Terebratula repeliniana*, d'Orb., as at Novion, but which shows its relation to the overlying rocks by its numerous *Astarte supracorallina*, &c. The long lists of fossils given by Buvignier as coming from his two divisions of the Coral Rag, of which the present is his *a*, contain many species in common, especially *Diceras arietinum*; nevertheless there can be little doubt of their corresponding with beds showing more distinctness further north. We find therefore the same subdivision of rocks, here referred to the Corallian, as in the Ardennes, namely a variable mass of coral-bearing or crinoidal limestone below, with *Cidaris florigemma*, and a more compact and oolitic stone above, with many *Nerinææ*, and an occasional *Diceras*. Hébert (21) thinks to divide the lower part into two portions, the base a shell-bed with *Cidaris florigemma* and the corals above; but the extreme variability of these rocks, and the occurrence of the characteristic urchin throughout all the modifications, render such a division valueless.

In this neighbourhood the first examination of the higher beds has been made along the road leading from Verdun westwards to Clermont-en-Argonne. Leaving the town by the fort on the northwest, one's position is accurately determined by observing the great coral-reefs on which the foundations are built, associated with the gasteropod-bearing intercoralline brash, followed in the railway-cutting by the massive rocks of the Nerinæan series as seen on the opposite side of the river. Succeeding these at once are more marly rocks than any seen before; in fact they are alternations of marls and flaggy earthy limestones, with here and there a bed of oolitic rock, a lumachelle of *Exogyra bruntutana*, or a lithographic limestone. The thin beds having their surfaces crowded with *Astarte supracorallina*, indicate with certainty the horizon. Rocks of this description occupy the country for a distance of five miles, till the lowest Virgulian lumachelle is reached, and seem to be rather uninteresting and barren. Nevertheless Buvignier describes the lithographic stones as massive, and overlain by an irregular pisolite having the fossils as casts, including *Diceras* and *Cardium Buvignieri*, a species which appears to be not different from *C. corallinum*. This would seem to indicate a repetition of the Diceras-beds at a higher horizon than the first, namely immediately beneath the Virgulian; and the list of fossils given as from the upper portion of the Astartian limestones contains several species usually of a lower horizon, such as *Lima æquilatera*, *Pecten articulatus*, *Chemnitzia heddingtonensis*, *Natica globosa*, &c. These pisolites are said to occur in the very district now under notice; but though the various sections were duly searched, no such rock was observed in the required position. At Baleycourt quarries were seen in which the stone was very rubbly; but it had the aspect entirely of a redeposited material with the fossils in it *remanié*, and not at all like the true Diceras-beds of the Haute-Marne. With this exception, no change in the character of the rocks is observable till the lumachelles with *Exogyra virgula* are reached. If therefore any portion representing the Pterocerian beds is to be found, it must be sought either in the beds containing *E. virgula* or in the lithographic limestones below. The latter are credited with an enormous thickness (400 feet), and obviously include much more than is usually placed in the Astartian beds. In point of fact, there seems little to characterize the beds here; and their subdivisions must be left somewhat doubtful.

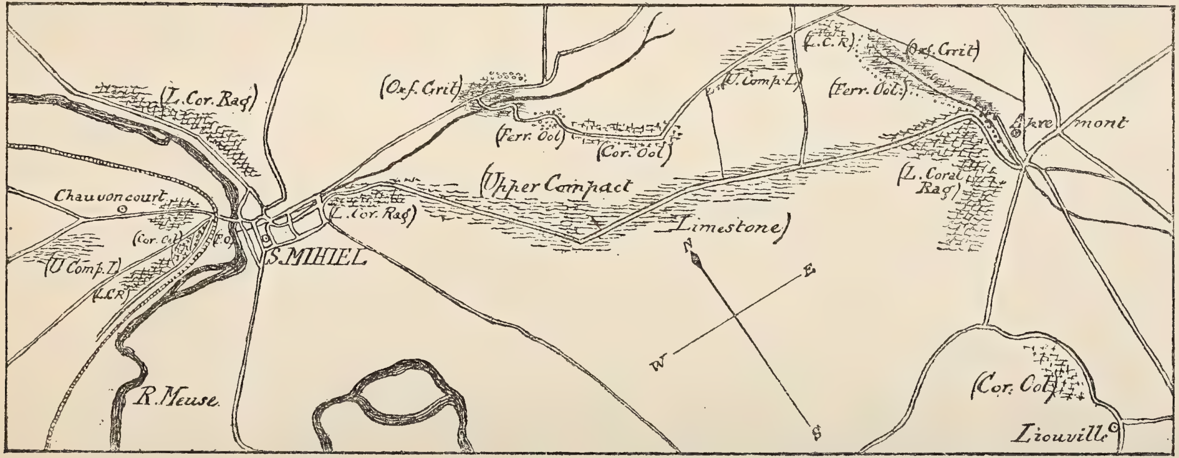
In the Virgulian marls which follow we have fortunately an admirable landmark, both because the abundance of the little oysters (which in themselves make half the bed) renders these marls immediately recognizable, and because the variety of their other fossils gives good materials for correlation. At the cutting of Nixéville the dark marls with *E. virgula* occupy the lower 12 feet, and white chalky limestones the upper 20 feet; neither therefore is seen in its full thickness. For a considerable distance to the west, alternations of these two forms recur, the marls being the last seen beneath the overlying lithographic limestone. The whole series does not appear to occupy so great a thickness as the lower Astartian beds. The white limestones are extremely fossiliferous, the most abundant shells being *Pleuromya Voltzii*, *Pholadomya acuticosta*, *Cucullæa texta*, and *Terebratula bisuffarcinata*. The other fossils observed were *Pterocera Ponti*, *Chenopus musca*, *Chemnitzia gigantea*, *Thracia lata*, *Mactromya rugosa*, *Ceromya excentrica*, *Cardium Bannesianum?*, *Trigonia Merian* *T. Juddii*, *Pinna granulata*, and *Nucula Menkei* and *Astarte supra-*

corallina. In spite of the last-named, which is thus seen to have rather a wide range, the fauna is essentially Lower Kimmeridgian, and may be well matched in the body of that clay in England. For purposes of comparison in the basin of Paris itself, the *Terebratula*, *Pholadomya*, and *Ceromya* should be especially noted. Fragments of coronate Ammonites which might belong to *A. gigas*, recorded by Buvignier, were seen; and it may be noted that *A. longispinus* is mentioned as occurring; but there is nothing except the first-named to unite this to the Upper Kimmeridge of England. Hence, therefore, there is no probability of the overlying rocks being of Portland age, as they are called by Buvignier.

In this locality the rocks which succeed the Virgulian beds at Dombasle are barren, lithographic, but somewhat argillaceous limestones, in remarkably uniform beds of from 8 to 12 inches thickness, with thin bands of intervening clay, thus presenting a well-marked lithological character by which they may be distinguished from the lower lithographic limestones. They become more rubbly towards the top, but, except for lumachelles of small oysters of unknown species, contain scarcely a single fossil. They occupy a considerable area, and must be nearly 100 feet thick; but even Buvignier only records four fossils:—*Ammonites gigas*, *Pleuromya Voltzii*, *Cardium Dufrenoycum*, and *Patella suprajurensis*. Nothing higher is to be seen in this part of the country, as the lithographic limestones extend to the alluvial plain separating the Jurassic area from the cretaceous escarpment.

We may next examine the country 25 miles further south from St. Mihiel and Commercy to Bar-le-Duc. The first-named is celebrated for the magnificent fauna of its Rag-deposits, and has been described separately by Buvignier. The escarpment begins about five miles to the west of the town, as at Apremont; but inliers close at hand enable us to recognize the Calcareous Grit, here still more nodular, with *Rhynchonella Thurmanni* and *Ostrea dilatata*, and the overlying Ferruginous Oolite, retaining the same characters that it has further north. But the limestones which succeed these have a much more extensive development. At the grand section exposed on the descent to Apremont, the actual base is not seen; but the rubbly unstratified mass appears to begin at once. It is here full of unrecognizable Thamnastræan corals (which appear to have been rolled), and abundance of *Hemicidaris crenularis*, *Cidaris florigemma*, *Apiocrinus Roissyanus*, *Terebratula maltonensis*, and *Pecten vimineus*. There is a thickness of about 120 feet, all made of similar material except near the top, where about 16 feet is made of massive crinoidal limestone as near Verdun. This latter type, therefore, as there, is subordinate to the Coral Rag; and we hence learn the age of the magnificent freestones of this character worked about seven miles to the south at Lerouville, where the quarries have a 100-foot face, all of the same material, with occasional *Cidaris florigemma*, *Terebratula insignis*, and other fossils. We note also that, whereas near Verdun the coral-beds formed the capping to the crinoidal limestones, here the latter lie at the top or nearly so, and no definite position in the

Fig. 3.—*Map of Country around St. Mihiel.* (Scale 1 : 80,000.)



Coral Rag can be assigned to either of these forms. Above the Coral Rag, on the road to St. Mihiel, are the more compact, almost lithographic limestones with *Nerinææ* as before, occupying a wide expanse of country. So far, therefore, the Verdun form is fairly continued; but when we examine the exposures seen in other valleys an interesting modification is observed. The deeper sections on the right bank of the Meuse show the base of the Coral Rag to be occupied by far more oolitic and regularly-bedded stone than any seen at Apremont; but on the left bank, quite close to St. Mihiel, a recent cutting gives a first real indication of something corresponding to our true Coralline Oolite. At the base of this cutting is 8 feet of Ferruginous Oolite crammed with fossils—*Ammonites convolutus* ?, *Pholadomya decemcostata* and *P. deltoidea*, *Mytilus pectinatus*, *Perna quadrata*, *Pecten articulatus*, *Ostrea dilatata*, *Rhynchonella lacunosa*, *Terebratula bucculenta*, *Collyrites bicordatus*, *Dysaster ovalis*, and others. Next comes more than 6 feet of a rather sandy limestone, not exactly oolitic, but thick-bedded, in which no *Cidaris florigemma* or *Pecten vimineus* could be found, but such fossils as *Ammonites plicatilis*, *Pseudomelania striata*, *Pholadomya deltoidea*, *Holectypus depressus*, and *Stomechinus* sp. abound. This mass is equally distinguishable from the Ferruginous Oolite and from the Coral Rag, and occupies the place, hitherto unrepresented, of those deposits which in England form a basis for the latter. The thickness of this mass is not well seen here, and is comparatively unimportant; but at Creué, 8 miles N.E. from here, Buvignier has described some "lower white limestones" occupying the same position, 250 feet in thickness; and the same occur also to the south of Apremont at Liouville, and are therefore more or less alternative with the Rag, the great thickness of which may be due to its filling up the hollows between the lenticular masses of the "coralline oolite" below. These limestones contain a fauna very distinct from that of the Coral Rag: urchins are almost absent; Myacidæ abound; and the whole assemblage is much more like that in the Ferruginous Oolite, *A. plicatilis* being the most abundant cephalopod. It differs, however, from the fauna of the latter rock in the absence of the characteristic urchins, crinoids, brachiopoda, and belemnites. In Buvignier's list 15 of its fossils are common to the Coral Rag, and 34 to the Ferruginous Oolite; but the latter is only 18 per cent. of the number found in both, so that by any method of percentages these limestones should be reckoned distinct.

Above the section already referred to, on the left bank of the Meuse, are about 80 feet of Coral Rag, most massive below, with old *Thamnastrææ* above, and containing all the usual fossils; and on the ascent of the hill comes on at once a great thickness of beautiful pure white oolite containing scarcely a fossil, though a *Corbis* and *Diceras* were noted; all this, therefore, only continues what has been seen before. What lies above has not been seen; but detailed accounts of it as exposed in the cuttings between Lérouville and Loxéville are given by Hébert (21). At Vadonville is seen at the base a great mass of white limestones, finely oolitic, but in places almost pisolitic, stated to be 300 feet in thickness *; and above them occur 150 feet of oolitic beds with various-sized grains, some pisolites, nodules, and many specimens of *Diceras*. The whole of this mass is considered by Prof. Hébert to be above the white limestones of Novion and Verdun, which would place them in the Astartian of Buvignier, but that he considers them to be absolutely wanting to the north of St. Mihiel. From their position in relation to the great crinoidal limestones of Lérouville, however, not 1800 yards away, their lower portion can be nothing else than the Novion limestone; and we learn that at this spot the peculiar pisolitic character of the Diceras-beds begins to be observable in this portion of the series towards the top. It is remarkable that no mention is made of this in Buvignier's work, though the spot is coloured as Corallian. The next cutting, 2¼ miles to the west, is also described by Prof. Hébert. Here the base is occupied by the same pisolitic Diceras-beds, their continuance being accounted for by some folds and reversed dips observed. This bed is declared by Buvignier (22) to be distinct from that at Vadonville, and to belong to the pisolites he has described from the Astartian. His description, however, of the cuttings is by no means clear (13), while Hébert's is precise and definite. Above these pisolitic beds come a few feet of oolites, and then a mass of non-oolitic marly limestone with conglomerates and *Ostrea deltoidea*. The same series of cuttings reveal Virgulian beds further to the east at Loxéville, with many fossils common to the Astartian beds, and, finally, the lithographic "Portland" † limestones (see 21). This is well-developed in the neighbourhood of Bar-le-Duc, forming the main mass of the hills. The carious limestones above are well-marked, with their hollow tubes filled with a brown earth. This is supposed by Tombeck to be the original material, and the limestone to have formed afterwards; but this can scarcely be the case, as there are in this district many fossils in the limestone with their interiors formed of the matrix but the shell gone. The assemblage of these appears to indicate very shallow-water conditions, as though here one were at the natural boundary of the deposit; they are mostly small and simple. Those found are *Alaria dionysea*, *Mactromya rugosa*, *Plectomya rugosa*, *Lucina aspernata*, *Corbicella Moreana*, *Lithodomus vietus*, and *Cardium pesolinum*?. We have very little assistance here towards correlation with our English rocks, and none towards placing these on a level with the Portland Limestone.

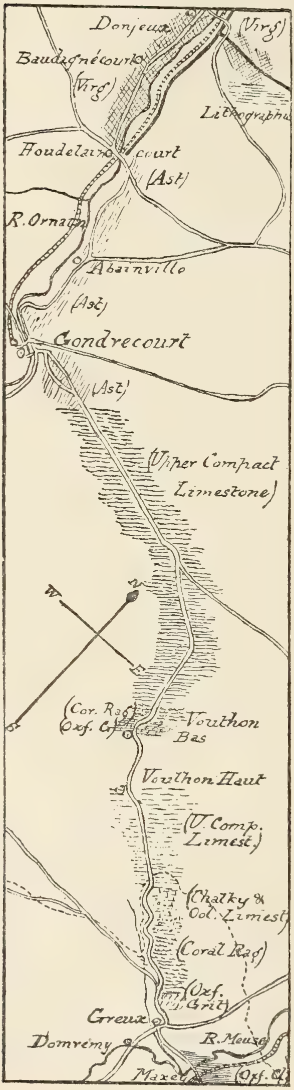
The highest beds seen here are a variable series of rather dirty-coloured stones with sands &c.; but one remarkable rock requires special notice. It is the "vacuolar oolite," in which, so to speak, there are no oolitic granules, though once there were; each granule has been dissolved, the intervening matrix alone remaining to form a spongy rock. This becomes in places almost a lumachelle of *Corbula*

* The thicknesses given by Prof. Hébert are always very large when *estimated*, and require to be somewhat reduced to bring them into comparison with the *estimates* of other geologists.

† The names used by the describers are adopted until the amended nomenclature is proposed at the end of this paper.

mosensis; and the next abundant shell is *Astarte rugosa*. Buvignier records also *Trigonia gibbosa*, but with doubt. These beds may very well represent the true Portland Limestone, which is also characterized by *Astarte rugosa*; but this question will be decided later on.

Fig. 4.—*Map of Country between the Meuse and Ornain.* (*Scale* 1 : 80,000.)



One more traverse completes our study of the Meuse department. This is about 25 miles to the south, but runs N.W. to S.E., the general trend of the strata changing near the extremity of the department to be N.E. and S.W. instead of N. and S. The whole series spreads about $8\frac{1}{2}$ miles on either side of Gondrecourt, actually commencing within the Vosges department.

The lowest beds are exposed at Greux, on the Meuse; and we still see the nodular calcareous grits at the top of the Oxford Clay, here more approaching what could be called a "terrain-à-chailles" than anywhere else, and still characterized by *Rhynchonella Thurmanni*. No sign, however, of the Ferruginous Oolite was observed; and Buvignier does not place it here on his map. It has therefore probably died out; for it is not seen again to the west. Neither is any thing like the Creué Limestone or "Coralline Oolite" seen; but the great mass of Coral Rag immediately succeeds. This consists of a rubbly rock, in places oolitic, without any corals, yet of that peculiar appearance which indicates the beds associated with them; and all the usual fossils abound, such as *Cidaris florigemma*, *Hemicidaris crenularis*, *Mytilus angulatus* (*jurensis*), &c. It is succeeded by a white chalky limestone with numerous hollow branches as of decayed corals, such as are seen at Novion. Some beds are flaggy; but all very barren of fossils. Above comes 12 feet of strong beds of oolitic and non-oolitic limestones, which are worked for building-stone when thickened out in the neighbourhood; and, finally, coarse-grained thin-splitting oolites occupy the summit of the hill. There is thus no proof of our having here reached the top of the limestones; and yet these are at least 300 feet above the Oxford Grit, all of which must be placed in the Coral Rag and Supracoralline beds. The continuation of the route, however, reads us a very instructive lesson. On consulting Buvignier's detailed map it will be seen that behind this hill there is a long tongue of the lower rocks crossing the road in the valley. Little is to be seen on the descent of the hill; but on the next rise at Vouthon Bas, the nodular Oxford Grit is seen in the village, and above this successively a shelly limestone full of *Cidaris florigemma*, massive oolitic rocks, thin-bedded oolitic rocks, and then the lithographic limestone—in a word the same succession as before, but in this instance crowded into a space which certainly cannot exceed 50 feet. So great a change in thickness in a distance of less than 3 miles gives an idea of the very local and fragmentary character of the Corallian rocks.

The greater part of the distance to Gondrecourt, about 5 miles, is occupied by compact, almost lithographic limestones, with no fossils visible. These appear to be placed by Buvignier, from the colouring of his map, as Astartian. They nevertheless occupy the position of the great masses to the north of Verdun, and perhaps also east of St. Mihiel, which are coloured Corallian; but in the absence of fossils it is difficult to say to which they should be joined. In this traverse, as in the others, but little sign is seen of the pisolitic Diceras-beds; only some coarse-grained oolites are seen. Hence the peculiar character so well seen further west is here only occasional, or occupies too small a space to be easily discovered.

Near the entrance to Gondrecourt these lithographic limestones are succeeded by and intermixed with rubbly beds with many fossils. A thickness of about 40 feet is seen, towards the top of which *Terebratula subsella* is abundant. Similar stone is continued for nearly a mile on the other side of Gondrecourt, and gives a very good idea of the Astartian beds in this district. The fossils here noted were *Terebratula* sp. (perhaps the young of *T. subsella*), *Pterocera Thirriæ*, *Thracia lata*, *Pholadomya Protei*, *Isocardia obovata*, *Ceromya excentrica*, *Pleuromya rugosa*, *Mytilus opisoides*?, and *Nautilus inflatus*. *Exogyra virgula* is not seen in these beds, which are almost as argillaceous as the overlying series, especially if we include in them all that lies below the first undoubtedly Virgulian bed; but no pisolitic beds are seen along the road. The base of the Virgulian occurs at Houdelaincourt, about 3 miles north of Gondrecourt, where a mass of chalky limestones forms a bank 40 feet in height, the upper part of which yields all the fauna of Nixéville, e.g. *Ammonites longispinus*, *Pholadomya multicostata*, *P. Protei*?, *Astarte supracorallina*, *Pinna granulata*, and *Pecten suprajurensis*. Above this come the marls full of *Exogyra virgula*, then more chalky limestones with *Pleuromya Voltzii*, and finally more marls and marly limestones such as are seen in a cutting further on. This cutting, made for the Marne-and-Rhine canal at Demanges, has been described and drawn by Buvignier. It shows well how argillaceous the Kimmeridgian is here, being composed of quite as much clay as stone, which is an exception to its usual character in France. About 40 ft. is exposed; but this does not include any lumachelles of *Exogyra virgula*, though that oyster occurs with others. The nodular bands are very fossiliferous, and include more stony beds at the base, with *Pholadomya multicostata*, *Gervillia kimmeridiensis*, and *Cucullæa texta*, and in more marly beds *Pterocera mosensis*, *Trigonia Voltzii*, *T. concentrica*, *Astarte scalaris* ?, *Pleuromya Voltzii*, *P. donacina* ?, *Pecten suprajurensis*, and *Terebratula subsella*.

This description of the beds which intervene between the Corallian and "Portland" limestones, though doubtless indicating that some division might be adopted, does not tend to magnify the importance, in this district at least, of the three groups—Astartian, Pterocerian, and Virgulian, all of which would be included in England in the body of the Lower Kimmeridge. There is a community of fauna which shows them all to be too intimately united for any wide separation. Above the fossiliferous Virgulian marls of the Demanges cutting comes immediately the unfossiliferous lithographic limestone of the so-called "Portland" series, occupying all the summits of the hills; but no special observations were here made.

3. *The Haute-Marne Department.*—The development of the Upper Jurassic rocks in this department has received more study and raised more discussions than that in any other place. It is consequently considered by many the typical region in the Paris basin, and is used as a term of comparison in every attempt at correlation. Lying opposite the strait which connects the basin of Paris with the Jura, its lower part appears to partake of the character of the Swiss rocks; and its upper part is more complete than anywhere else in the same range. Although it is therefore of the highest importance that its rocks should be correctly described and interpreted, the difficulties of its natural situation appear to have been increased by its illustrators, and one would suppose from their writings that it was of most anomalous structure. The earliest description was given by Royer (4). Being the simplest, this was in some respects the best; and it will be well to quote it for comparison with the most recent and complicated. Royer divides the series as follows:—

A. Portland. OOLITE OF BARROIS.
- *a*. Carious limestones.
- *b*. Nodular compact limestones.
- *c*. Lithographic limestones.

B. Kimmeridgian.

C. Astartian.
- *a*. Nodular and oolitic beds.
- *b*. Compact limestone.

D. Coralline oolite.

E. Compact Corallian limestone.
- *a*. Thick limestone.
- *b*. Marly limestones passing to Oxfordian; *b'*. Rubbly coral limestone.

F. Upper Oxfordian marls, almost without fossils.

G. Middle Oxfordian.

H. Lower Oxfordian.

Various changes have since been made in this classification, partly by way of expansion, but partly by way of alteration; and an almost interminable series of Notes by M. Tombeck have led to the development of a classification which is exceedingly complicated, and which in several important points it seems impossible to accept. As published by MM. De Loriol, Royer, and Tombeck (50), and modified by the last named (55), it is as follows:—

PORTLANDIAN.

1. Zone of *Cyrena rugosa.*
   - *a.* Upper grey-green limestones.
   - *b.* Vacuolar oolite.
   - *c.* Lower grey-green limestones.
2. Zone of *Cyprina Brongniarti.*
   - *a.* Tubulous limestones.
   - *b.* Spotted limestones.
   - *c.* Carious limestones.
3. Zone of *Ammonites gigas.*
   - *a.* Bure oolite.
   - *b.* Limestone with *Amm. irius.*
   - *c.* Marls with *Hemicidaris purbeckensis.*
   - *d.* Lithographic limestone with *Amm. rotundus.*

KIMMERIDGIAN.

1. Zone of *Amm. caletanus,* = Virgulian.
   - *a.* Alternations with *Amm. erinus.*
   - *b.* Marls with *Amm. eumelus.*
2. Zone of *Amm. orthocera,* = Pterocerian.
   - *a.* Perforated limestones.
   - *b.* Marly limestones with *Dysaster granulosus.*
   - *c.* Limestone with *Isocardia striata.*
   - *d.* Marls with *Rhabdocidaris Orbignyana.*
   - *e.* Marls with *Ceromya excentrica.*
   - *f.* Perforated limestone with *Pteroceras.*

CORALLIAN OR SEQUANIAN.

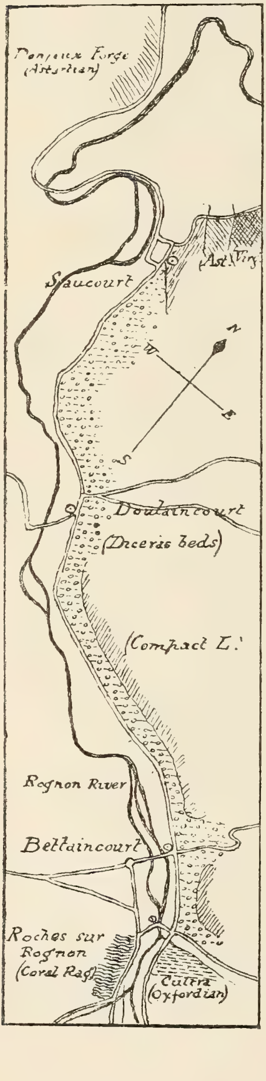
1. Second zone of *Terebratula humeralis.*
   Astartian limestone.
2. Second zone of *Cardium corallinum.*
   La-Mothe oolite.
3. First zone of *Terebratula humeralis.*
   - *a.* Lithographic limestones.
   - *b.* Saucourt oolite.
   - *c.* Limestones with *Nautilus giganteus.*
   - *d.* Upper rubbly limestone with *Cidaris florigemma.*
   - *e.* Limestone with *Amm. achilles.*
   - *f.* Limestone with *Amm. bimammatus.*
4. First zone of *Cardium corallinum,* and zone of *Hemicidaris crenularis.*
   - *a.* Upper marls without fossils.
   - *b.* Diceras-oolites, and lower rubbly limestones with *Cidaris florigemma.*
   - *c.* Lower marls without fossils.

OXFORDIAN.

Zone of *Amm. transversarius.*
- *a.* Beds with *Amm. Henrici* and *Amm. oculatus.*
- *b.* Beds with *Amm. Babeanus.*
- *c.* Beds with *Amm. Martelli.*

This is an exceedingly complicated classification; but it is necessary to give it in full, because points of discussion arise depending on its details. According to the descriptions given by Tombeck, all kinds of extraordinary developments of the Corallian rocks take place in this district, and many differences are observable from any thing found elsewhere; but though it may seem presumptuous to found any opinion upon a rapid survey, yet that survey, directed to the special examination of crucial spots, fails to reveal any thing very abnormal, though there are considerable differences when the rocks are compared with those already studied. In point of fact, an examination of the locality fails to comfirm M. Tombeck's conclusions in several important points.

Fig. 5.—*Map of Part of the Valley of the Rognon.* (Scale 1 : 80,000.)



The chief point necessary to establish is the true succession of the rocks which lie between the Virgulian and the Oxfordian beds. By the aid of a personal examination of the spots, aided by the definite facts recorded, when rightly interpreted, one may come to a pretty sound conclusion.

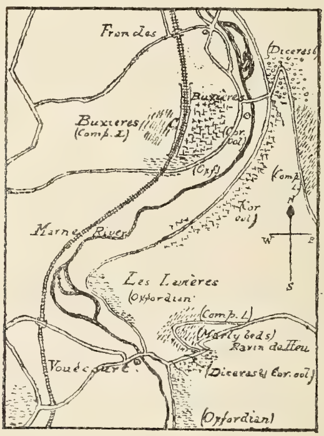
This portion of the series may be first examined in the valley of the Rognon. Passing down this valley from Andelot towards Donjeux, the Corallian rocks, in the form of rubbly limestones with *Cidaris florigemma*, are first seen on the left bank of the stream at Roche-sur-Rognon. Their base is not here well exposed; but is stated (19) to consist, in the neighbourhood, of disaggregated oolites with *Glypticus hieroglyphicus*, overlain by white coral-limestone. On the opposite side of the stream the rubbly limestones are themselves absent, their place being taken at Cultra by compact Oxfordian limestones, similar to those which occupy so much of the ground below them (by general dip) on the left bank. This is doubtless due to a fault; though Tombeck (65) actually thinks the rubbly limestones 100 feet thick have *changed* into this compact well-stratified form at a distance of 500 yards. A second cross fault cuts off Cultra from the cliff of Bettaincourt, where the great Diceras-beds occupy the ground down to the stream. The relation, therefore, of the two parts of the Corallian rocks is not here so clear as could be wished; but some portion of the Diceras-beds are seen to be lying on the top of the rubbly limestones further back at Roche-sur-Rognon; and at Reynel, about 3 miles to the east, Tombeck (55) describes an admirable section, having at the base Oxfordian marls with *O. dilatata*, then grey marls with *Cidaris florigemma* and *Hemicidaris crenularis*, next a mass of coral limestone with corals *in situ*, gradually becoming oolitic and then pisolitic as at Bettaincourt, the whole being 300 feet in thickness. Notwithstanding this section, however, he thinks (65) that the one form changes into the other.

The Diceras-beds at Bettaincourt, first seen here in a journey westwards in their full development, are marvellous deposits. They consist of rolled fragments of all sizes, coated with calcareous cement, and which in one sense may therefore be called oolitic grains; but they have been subjected to a very different variety of the process which produced the concentric coats of the latter. In oolites the process is tranquil, in these tumultuous and rapid, the whole presenting the appearance of a substratified heap of rubbish from a neighbouring centre of life, borne along by the ancient currents which swept through the straits of Dijon. Such beds might be supposed to replace, with almost any rapidity, the coral-growths from which they are derived, or to die out entirely. There are, however, great varieties in the Diceras-beds themselves—pisolites, large-grained oolites, suboolitic, and thin-splitting limestone alternating; and various groups of fossils are found in the various parts; but yet the whole is indivisible. With many *Dicerata* occur *Cidaris florigemma*, *Cardium corallinum*, and many rolled sponges. The other fossils noted were *Nerinœa sequana* and other species, *Littorina muricata*, *Isocardia striata*, *Corbis gigantea*, *Lima lœviuscula*, *L. pectiniformis*, *Trichites* sp., *Ostrea pulligera*, and *Terebratula maltonensis*. What the real thickness of these beds may be it is impossible to say; their stratification is so irregular, and their change of character in a lateral direction so marked, that all estimates are worthless. Perhaps 300 feet may be seen in the Bettaincourt hill-side if there is no *real* dip; but even more may be introduced in the five miles over which the deposit spreads. It is, of course, easy (50) to pick out one of the oolitic portions, and call it the "oolithe de Saucourt," and another above this, and call it the "oolithe de La Mothe;" but the actual oolites which occur at those places are not thereby proved to be superimposed, unless they are proved identical with these beds, which has not been, and cannot be done. The whole forms one great mass (here at its maximum of development), representing on the one hand the Novion and Vadonville limestones, and on the other the whole mass of the Diceras-beds further to the west. The upper portion is certainly more compact than the lower. On reaching Saucourt the peculiar character of the Diceras-beds is lost; and on ascending the hill we find the oolites above worked in a 12-foot face, and overlain by a shelly limestone crowded with *Rhynchonella pinguis*; this is followed by more compact limestone, some portion of which may possibly be slightly oolitic; but there is nothing remarkable to distinguish the whole series, nor is its relation to the Diceras-beds below very clear.

Succeeding these compact limestones comes no great thickness of irregular limestones, such as have been seen to characterize the Astartian beds near Gondrecourt; and on the top of the hill follow the marly beds with *Exogyra virgula* in lumachelles, and *Pholadomya acuticosta.* If any Pterocerian is to be made out here, it must be by a very close examination of fossils, which are not by any means abundant.

At the forges of Donjeux, about a mile further on, is a quarry in which the oolite of La Mothe is supposed to be seen. Here the top beds consist of the irregular Astartian limestones; and the base of the quarry is worked for massive rocks, which are on the whole compact, varying on the one hand to lithographic stones, or on the other developing a fair proportion of oolitic grains, but totally unlike the Diceras-beds, because like any other semioolitic rock. Here, then, is no repetition; and on the whole, with the exception of the remarkable Diceras-beds, the succession in this valley is very similar to, and certainly consonant with, what we saw in the last section in the Meuse department. The chief noticeable point is that the peculiar pisolitic character is exhibited rather at the base than towards the top of the mass.

Fig. 6.—*Map of Part of the Marne Valley.* (Scale 1 : 80,000.)



Now let us pass to the valley of the Marne. A complete section of the lower portion may be obtained by following the right bank of the river from Vouécourt to Buxières, and then mounting the hill-road. The base of the hill called "Les Lavières" is formed by well-exposed sandy marls and flaggy beds, which are very poorly fossiliferous, and appear to represent the "marls without fossils," the only fossils obtained being *Amm. marantianus* and *Arca rhomboidalis*, the latter a fossil of wide range. The amount of this material must be considerable; in fact, in the neighbouring cutting of Buxières about 50 feet is seen. Above these marls, on the road running north, are quarries of rock somewhat slipped out of place, but consisting of solid blocks of true oolites with *Amm. plicatilis*—a very good representative of a "coralline oolite." Soon a river-cliff is reached, by the side of which the road runs, and we have a continuous section with scarcely a break. First there is a shell-limestone, in parts oolitic, containing *Chemnitzia heddingtonensis*, *Neritopsis Guerrei*, *Cerithium inornatum*, *Nerinæa* sp., *Trigonia Etalloni* ?, *Lima læviuscula*, *Pecten articulatus*, *Ostrea solitaria*, *Rhynchonella corallina* ?, *R. pinguis*, and *Terebratula rotundata* ?. There are also numerous corals; in fact, in places towards the upper part the rock becomes a complete reef; but the corals are not commonly Thamnastræan, and the urchin is *C. Smithii* and not *C. florigemma*. Nevertheless these coral-growths must represent the Rag; for, traced upwards, the rocks become more oolitic, then pisolitic, and finally, without our being able to draw any line, we are fairly launched into the characteristic Diceras-beds with all their great masses of rubble, their *Diceras* and *Cardium corallinum*. The whole of these beds constitute a magnificent assemblage of limestones which can scarcely be less than 300 feet in thickness. There is no change here in a horizontal direction, as stated by Tombeck. The beds dip slightly to the north, which brings higher beds to the same level; but the Diceras-beds are not met with till we begin to mount; it is therefore, on the contrary, a vertical succession. The beds which overlie the Diceras-beds here gradually lose their pisolitic character and become marly and rubbly, but are often compacted into solid blocks. The fossils observed in these beds were *Pholadomya Protei*, *Ceromya striata*, *Mytilus perplicatus*, *Trichites* sp., *Ostrea gregaria*, and *Terebratula Leymerii*. These beds represent, apparently, the subdivisions C to F of Tombeck's first zone of *Ter. humeralis*, and have a thickness of about 60 feet. They are here followed by a somewhat more oolitic block capped with a bed of *Rhynchonella pinguis*, which may well be the continuation of the block quarried at Saucourt. Above this come compact, nearly lithographic limestones, which occupy all the summits of the hills. The whole succession is here therefore perfectly clear, and it is singularly like what has been recorded as seen at Reynel.

There is nothing in all this to indicate any thing abnormal, further than the characteristic inconstancy of the Corallian rocks. The Oxfordian strata, however, appear to have put on a different facies. There is here no Calcareous Grit with characteristic fossils, nor any Ferruginous Oolite; and the species of Ammonites are not those which are common to the east. Further down in the Oxford clay the zones appear to be continuous, and hence the new form of marls with

Ammonites marantianus &c. must have taken the place of the uppermost portion.

On account, however, of the many questions which have been raised about the Haute Marne, taken by the French geologists as their typical area of Corallian rocks, it is needful not only to make out the succession from the rocks themselves, but also to discuss the evidence brought forward in support of a different and more complex reading. The peculiar changes supposed to be here effected in the relations of the recognized Corallian rocks and those hitherto considered Oxfordian, and the generalizations founded on this, have been developed by degrees in numerous papers by M. Tombeck (45, 48, 50, 55, 57, 58, 64, 65, 66).

The "Marls without fossils," stated by M. Royer to underlie the Corallian, were first made to be their lateral equivalents (55), and afterwards (64) were divided into two parts; and the whole Corallian mass, when that occurred, was inserted between the two, which unite into one in its absence. Hence the fossils of these barren marls, especially *Amm. marantianus*, were considered Corallian; and wherever that species is found we are to look for the Coral-beds and Pisolites beneath it. Hence, too, the beds with *Amm. tenuilobatus*, which are said to come above those with *Amm. marantianus*, are to be placed in the Astartian instead of the Oxfordian. Now, whatever evidence there may be elsewhere to show the true position of these zones, the only evidence obtainable from the Haute Marne shows that the first zone lies *below* the Corallian.

The idea that the Corallian rocks change into marls depends on a comparison of the series in the valley of the Marne with that in the neighbouring valley of the Aube, and will be discussed later. The newer idea that they are to be intercalated is supposed to be proved in the valley of the Marne itself.

The river-cliff before mentioned, which skirts the right bank of the Marne from Les Lavières to Buxières, forms a semicircle of rocks having a fairly constant dip to the north. The radius of this semicircle is 1500 yards; and near the centre is a low hill, through which the railway passes in a cutting at a distance of only 1000 yards from the cliff. In this cutting it is said that the Diceras-beds, 300 feet thick at 1000 yards distance, have died out to a thin wedge, and may be seen lying in the midst of the marls (65) and the underlying rubbly limestones at the base. Neither of these statements can be accepted. The marls at the cutting are the continuation of those of Les Lavières, with exactly the same character: there are hard bands in them; but these are not Corallian; and the *top* of the cutting on either side is *covered* by the shelly limestones of the cliff and their fragments, with corals and *Pecten articulatus* &c. Here, therefore, the Oxfordian marls are seen to underlie the Corallian limestones. The Corallian limestones lie very slightly unconformably on the marls; so there may be something wanting here.

Another locality supposed to prove the same is at Vouécourt, two miles to the south (62). Above this village is a ravine leading east (Ravin du Heu), and a road sloping up the hillside to Viéville on the south (Côte du Noeulon). In the first the marly limestone "à *A. Holbeini* et *A. marantianus*" is said to be seen above the Diceras-beds; and in the second the Diceras-beds are said to be reduced to almost zero in the midst of the clays. If "*A. marantianus* is found" (in beds which lie?) "above 50 metres of Diceras-beds at Baxières," and (in beds which lie?) "above 30 metres of the same at Heu," still one swallow does not make a summer, and the rare occurrence of such a fossil would no more make the zone of *Amm. marantianus* Corallian than the occurrence of species so near to *Amm. cordatus* that they cannot be distinguished in Supracoralline or even Kimmeridgian beds makes the zone of *Amm. cordatus* a part of the Kimmeridge Clay. The actual section seen at Vouécourt is quite consonant with all that has been seen before, except that in the Ravin du Heu the lower part of the section is much distorted, and the Corallian beds on the north appear to be let down, as by a fault, to too low a level in relation to the Oxfordian on the south. The section commences at the top with compact limestones, as at Buxières; then, below, come rubbly limestones with abundant *Terebratula Leymerii*, *T. tetragona*, &c., also *Rhynchonella pinguis*, *Pleuromya Voltzii*, *Anatina magnifica*, *Mytilus perplicatus*, *Pinna granulata*, *Pecten inæquicostatus*, and *Nerita Royeri*. Next follow marls and marly flags containing the same Brachiopoda, *Mytilus*, and *Pecten*, with *Arca rhomboidalis* and *Pholadomya cor*? These are the beds which contain *Amm. marantianus*, according to Tombeck; if they do, it has not its usual associates, and is therefore *out of its place*. Below comes a great mass of limestone capped by a rosy large-grained oolite; but the base is not seen, the whole being so disordered. In these were seen *Lima læviuscula*, *Pecten articulatus*, and *Rhynchonella corallina*. No doubt the Diceras-beds do not here make such a show; but the succession above shows that we are at their top, and there may be much more than appears. It is *below all this* that the whole road along the Noeulon is cut; and it shows only the marls and marly limestones of the Les-Lavières and Buxières cuttings.

All the other sections in and near the Marne valley quoted by Royer or Tombeck, and those seen by the Geological Society of France on their visit in 1856 (19), are perfectly consonant with the present reading, and may be easily interpreted.

To complete the account of these lower beds, as developed in the department of the Haute Marne, we must make a digression towards the west to Maranville and La Mothe. At the first locality on the left bank of the Aube we are supposed to recognize the Corallian in the midst of the marls; there is, however, nothing Corallian about them. The rocks seen in the hills here are a series of marly limestones far more argillaceous than any seen before, having a thickness of 120 feet. They are most lithographic above, and most marly below, the intervening portion being most fossiliferous. The fossils seen are Oxfordian, viz. *Alaria bispinosa*, *Astarte striatocostata*, *Littorina Meriani*, *Ostrea multiformis*, *Exogyra spiralis*. There is nothing, therefore, here to identify any portion as having a position above the Diceras-beds; but the whole corresponds to the marls below. Though nothing is seen above these Oxfordian rocks on the left bank of the Aube, the whole country on the right bank to near La Mothe is occupied by limestone rocks very similar in character to those at Buxières, though only occasionally observable. At La Mothe itself the most characteristic rock is exactly of the Doulaincourt and Buxières type, and totally unlike any thing called La-Mothe Oolite elsewhere; beneath it is a thick mass of large-grained oolite (perhaps 30 feet), worked for building-stone at Curmont, below which here, in an excavation, are seen the shelly limestones as at Buxières. The succession is exactly the same, and the fossils similar.

In Royer's first description (4) these Diceras-beds were placed on the same level; and it was after his visit to the valley of the Yonne, where two Oolites are developed, that he endeavoured to find two also in the Haute Marne. The Oolite at La Mothe lies on a mass of compact limestone, which he traced to Soncourt, and there found rubbly beds at the base. These rubbly beds he apparently took for the thinned representative of the whole of the Corallian. Numerous sections seen and described show that (as at Buxières) the base of the Corallian is rubbly and Coralliferous; but it has never been proved that the Oolite of La Mothe overlies any such beds as the rubbly and oolitic limestones which cap the Diceras-beds at Buxières; on the contrary, such beds, with their usual Brachiopoda, are seen above the Oolite in the neighbourhood of La Mothe; and these are followed by compact, almost lithographic limestones; but whether immediately or not cannot be certainly made out. Above these come the irregular limestones which usually indicate the Astartian zone; and on the hill of Colombey-les-deux-Eglises are the marls full of *Exogyra virgula*, the whole being very parallel to what is seen above Saucourt. The difference in elevation between Curmont and Colombey is about 150 feet.

On the undisputed Astartian and Virgulian of the Haute Marne no special observations have been made; but it may be noted that the Geological Society of France found in the rubbly limestones of Donjeux, associated with several *Nerinææ*, *Natica hemisphærica*, *N. turbiniformis*, *Pholadomya Protei*, *Plectomya rugosa*, *Ceromya excentrica*, *C. obovata*, *Exogyra virgula*, *Ostrea solitaria*, *Rhynchonella pinguis* (?), *Terebratula subsella*, *T. Leymerii*, and *Holectypus corallinus*. From Joinville northwards we have the most complete development within the basin of the "Portland" rocks. At that town great masses of lithographic limestones are quarried, all with the peculiar clay bands dividing them into thin blocks, and containing virgulian lumachelles here and there. They have a great thickness, and are very unfossiliferous; there are some alternations of marls and earthy limestones. and a block of oolite at what may be conveniently called the top. The Ammonites that have been found in them—*A. gigas*, *A. suprajurensis*, and *A. rotundus*, together with *Trigonia Pellati*, *T. Cottaldi*, *Cardium Foucardi*, *Myacites jurassi*, *Pecten suprajurensis*, with others recorded by Tombeck, are sufficient to correlate these limestones with what has been known elsewhere as Lower Portlandian, though the facies is too different to permit us to compare it directly with the portion of the English Kimmeridge Clay corresponding to it. The next portion of the series, called by Tombeck the zone of *Cyprina Brongniarti*, consists of three subdivisions, each of which has sufficiently marked lithological characters to be recognized without fossils; and they are admirably shown to the north of Joinville. The thickness of this portion is estimated at 160 feet, and it is far more fossiliferous than the lower group, as we have seen it to be near Bar-le-Duc. Still the line between the two may be considered arbitrary, and very probably does not correspond to the subdivisions in the Department of the Yonne. *Pinna suprajurensis*, after which the series is named in that locality, occurs here in abundance in some beds above the Bure Oolite, which are not carious. The whole is well seen above Rachécourt, as Tombeck says. The chief fossils observed in this series are *Cyprina Brongniarti*, *Mytilus icaunensis*, *Anatina inæquilatera*, *Corbula mosensis*, *Cardium Dufrenoycum*, *Cyprina implicata*, *Pecten nudus*. These beds are here better developed than in the Meuse, and yield more data for comparison. They are succeeded by a small thickness of unfossiliferous, dirty-coloured stones, which form the possible representative of the "Middle Portland" of Boulogne.

Above all these rocks, and seen in several places to continue without discordance into them, are the remarkable beds placed as the "Zone of *Cyrena rugosa*." They partly consist of grey flags, sparkling with minute crystals and crowded with *Corbula? inflexa*, and partly of vacuolar oolite, worked in thick beds free from fossils, having here and there bands of shells, the principal of which are *Astarte rugosa*, *Corbula inflexa*, and *Avicula rhomboidalis*. The beds have the appearance of having been formed in shallow water. These rocks, of which the 16 feet worked at Chevillon may be a maximum, appear to be separated from all below them, both in character and the greater number of the fossils; and under these circumstances, perhaps, the single shell (*Astarte rugosa*) which they have in common may suffice for a bond of union with the English Portland rocks. The development here is extremely restricted, these rocks not having a range of more than 30 miles.

4. *Department of the Aube.*—We here come under the guidance of Leymerie (7), whose work, though now old, is admirable; and very little attention appears to have been paid to the department since his time. His classification of the rocks is as follows:—

UPPER JURASSIC.

1. Portland limestone, 330 feet.
2. Marls and limestones, with *Exogyra virgula*, 250 feet.

MIDDLE JURASSIC.

1. Astartian limestone, 320 feet.
2. Nodular white limestones = Coral Rag, 40 feet.
3. Lower Coral limestone.
   - *a.* Compact limestone, 80–100 feet.
   - *b.* "Levique" limestone, 50 feet.
   - *c.* Oolitic shell-limestone, 80–100 feet.

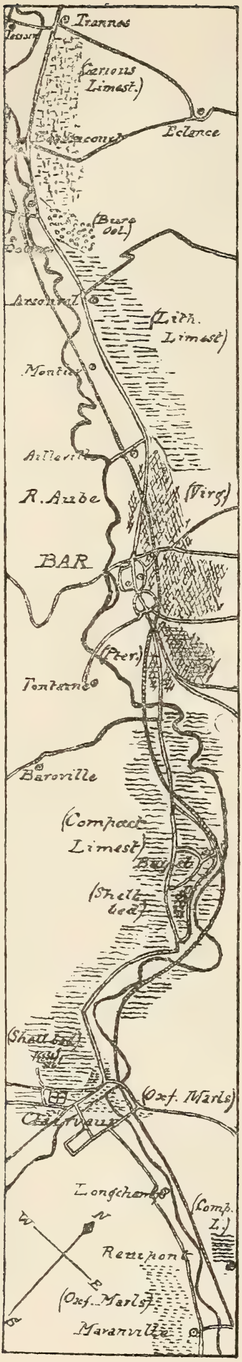
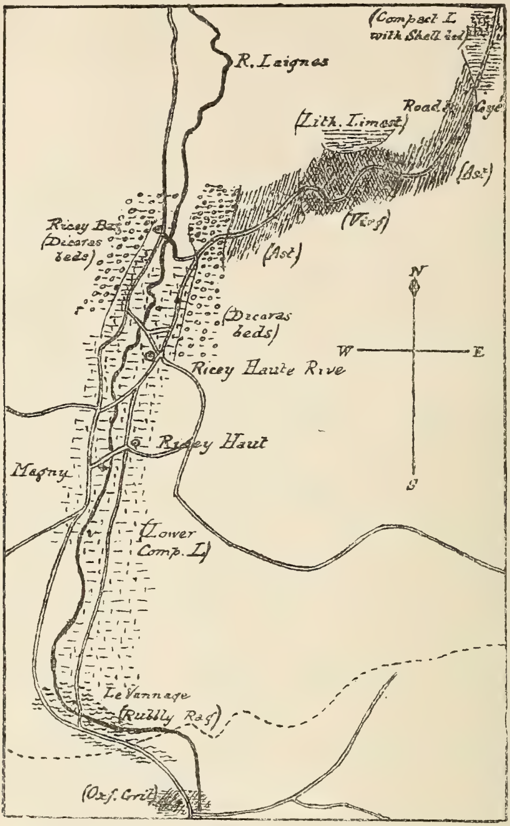


Fig. 7.—*Map of the Valley of the Aube, near Bar.* (Scale 1 : 80,000.)

Our first traverse is down the valley of the Aube, on either side of Bar-sur-Aube. At Clairvaux, not very far north of Maranville, near the river, there are great cement-works, where cement-stones, more or less sandy, and interspersed with marly beds, are worked over a thickness of 40 feet or more. These contain abundant fossils; the chief noted were *Cerithium muricatum*, *Pholadomya canaliculata*, *P. cingulata*, *Trigonia perlata*, *Anatina magnifica*, *Goniomya sulcata*, *Pinna lanceolata*, *Gervillia aviculoides*, and *Exogyra spiralis*. There really cannot be very much doubt whereabouts we are in the series here; it must be the top of the Oxfordian, somewhere on the level of the Lower Calcareous Grit. These, in fact, appear to be the beds that are missing a little further to the east (at Buxières), and probably on a higher horizon than those at Maranville. In any case the fauna is perfectly distinct from that of the somewhat marly limestones which lie *above* the Diceras-beds at Vouécourt. In Leymerie's lists no such assemblage is noticed; and it would seem that these beds were not open to his observation.

The immediately overlying rocks are not well observable here; but there appears no sign of rubbly Coral Rag or of Diceras-beds, in place of which the marly beds become more sandy, then more solid, and finally change into a massive limestone. This is not to be wondered at, when we observe the great reduction the Diceras-beds have suffered between Buxières and La Mothe. We are here introduced, in fact, to the feature which characterizes much of the western extension of the Upper Jurassic rocks: they tend more and more to become a uniform mass in which recognizable rocks of peculiar constitution are mere occasional occurrences. The solidity of the limestones in this district is well shown in a quarry-face of 60 feet, the base of which is reached by a continual ascent through a stony ravine; and here, high above the cement-stones, perhaps 200 feet, we find a fossiliferous zone, similar to that at Saucourt, belonging to the compact limestones above the Diceras-beds. This contains *Arca lineolata*, *Mytilus longævus*?, *Trigonia Etalloni*, *Avicula obliqua*, *Pecten suprajurensis*?, and *Rhynchonella pinguis*. Towards the top of the quarry the limestones become chalky. These great masses of course occupy the country for several miles; and thus we find this same fossiliferous zone three miles to the north at Bayel. Here, too, the *Rhynchonella*-bed lies at the base, and the upper part is chalky. *Cladophyllia* occurs here and there; and in addition to the same *Trigonia* and *Avicula*, there are *Pecten vimineus*?, *Cyprina callosa*, Röm.?, *Terebratula tetragona*, and *Cidaris Smithii*. Traced still further upwards, the rocks become lithographic and unfossiliferous. The whole of this mass was considered Astartian by Leymerie; and hence he gives 320 feet as its thickness; but it plainly represents every thing which lies between the Oxfordian and Pterocerian. The next recognizable beds are irregular somewhat marly limestones, with *Pteroceras Ponti* and *Mytilus acinaces*. In such a mass it is difficult to recognize Astartian beds; but it seems probable that some part at least of the lithographic limestones belong to them; and hence the overlying beds, which are irregular in character, and contain one of the characteristic fossils, are the best representatives of any thing that could be called Pterocerian that has been hitherto seen. On the north of Bar-sur-Aube the marls with *Exogyra virgula* are well exposed, but do not yield many fossils, the chief noticed being *Pleuromya tellina*. This portion of the series possesses but little interest, but is followed by the "Portland" lithographic limestones similar in character to those at Joinville, and containing a plicatiloid Ammonite like *A. biplex*. Above this is seen, near Bossancourt, another important Oolite in this series. It is the one which, in the Haute-Marne, is called the Bure Oolite, here developed to a bed of considerable importance, more than 6 feet in thickness, and worked in underground mines for building-stone. It is singularly free from fossils; but below it are some dirty-coloured oolites, with *Amm. suprajurensis* and small oysters; whilst above are thin-bedded rather chalky limestones, with oysters also, and the following fossils—*Cardium Dufrenoycum*, *Cardium Verioti*, and *Trigonia truncata*. These pass into varying limestones, amongst which are the beds containing great branching earth-filled hollows, hence known as the carious limestones. They are well developed—partly chalky, partly rubbly—all the way to Trannes, where a large quarry shows the last of the jurassic rocks in this district. In these beds, which would probably, if searched, reveal a good fauna, occurred *Lima suprajurensis*, *L. boloniensis*, *Pecten suprajurensis*, *Lucina fragosa*, *Terebratula subsella* (var. *minor*), and teeth of *Lepidotus*. We here therefore do not see beds so far up in the series as those of the Marne valley, no representatives of the spotted limestones or of the vacuolar oolite being preserved; but the lower portions seem to become more and more fossiliferous as we pass westward.

Fig. 8.—*Map of Part of the Valley of the Laignes.* (Scale 1 : 80,000.)



The next traverse, though not along the valley of a river, is an exceedingly instructive one, as we get an almost complete section from the Corallian to the uppermost beds. This is across the hill that intervenes between Gyé-sur-Seine and the Riceys in the south-western portion of the department. Commencing at the former place, we find a cliff cut at the road-side, and all the rocks laid bare. At the base is (1) shelly limestone, similar to that at the top of the Clairvaux section, with indications of bastard oolite, like the Diceras-beds of Doulaincourt, and containing crinoid stems and *Rhynchonella pinguis*. There is therefore still an absence here of the great Diceras-masses; and the type is conformable to that of the valley of the Aube. Next (2) are from 30 to 40 feet of chalky limestones, splitting into rather thin layers, with *Pholadomya cingulata*, *P. cor* ?, and *Anisocardia Legayi*. Above this comes (3) a 2-foot band of a curious blue earthy limestone, with globular masses of calc tuff. This seems to be a bed of separation between two groups of rocks; it contains few fossils, except *Pholadomyæ* (cf. *P. ampla*). If any definite line therefore can be drawn, it is above this that the Astartian zone should commence. Next comes (4) a mass of about 30 feet of solid light-coloured sublithographic stone, with two bands of remarkable character, made up of rolled fragments recemented, with *Naticæ*, *Pecten striatus*, *Ceromya wabrensis*, and abundance of *Terebratula Leymerii*. It is just such a band as this that Prof. Hébert (31) elsewhere thought a good line of separation, showing the distinctness of Astartian and Corallian beds; but, as it is obvious that they cannot both be such, they both lose their importance, and prove that there were frequent changes in the deposits about this period. This same feature is indicated by subsequent deposits in this section, in which are many rubble-beds alternating with lithographic limestones and occasional oolites. Such beds have a thickness of about 60 feet, and contain *Pholadomya Protei*, *P. rostralis*, *Thracia tenera*, *Pecten Tombecki*, *Terebratula Leymerii*, *Rhynchonella ? matronensis*, *Cidaris Smithii*, &c. This is followed by the Virgulian marls, full of *Exogyra virgula* and *Pholadomya rostralis*, for 16 feet, exposed in the roadside, but extending far up the hill, and finally surmounted by lithographic limestone, with *Terebratula subsella*. On continuing the route to the Riceys the descent of the hill shows a second section corresponding closely with the first, until the chalky limestones (2) are reached; but beneath these, instead of the shelly limestones with only traces of *Diceras*, is a large development of true rubbly Diceras oolite, of which 15 feet in sheer height are seen in one spot, although there may be much more of it. These beds form the cappings of the hills, and assist in producing the magnificent escarpments which overlook both sides of the river. Wherever these Diceras-beds occur they never require to be looked for; and where they do not form a marked feature it is pretty certain they are absent. The principal fossils noted were *Nerinæa umbilicata* ?, *Diceras arietina*, *Nerita Royeri* ?, *Trigonia Etalloni*, and *Rhynchonella matronensis*. Beneath these, on the west side of Ricey Bas, is worked a mass of 6 feet of a compact oolite, with few fossils in a crystalline state. Underlying this, again, is a considerable quantity of white chalky limestone, tending to be flaggy on weathering, and occasionally false-bedded. Of this there may be 60 or 70 feet, the principal fossils being *Pholadomya striatula*, *Avicula Gesneri*, and *Rhynchonella pinguis*. In downward succession we reach, at Le Vannage, a quantity of shelly limestone, with abundance of corals, in which *Pecten vimineus*, *Rhynchonella corallina*, &c. abound, but in which no *Cidaris florigemma* could be found. On crossing the boundary into the department of the Côte d'Or, at a very slightly lower level, there are numerous quarries in a calcareous grit, whose horizon is accurately fixed by the occurrence of *Trigonia spinifera*. In the last-named department there is a very considerable development of the lower coral-beds, with *Pecten vimineus* and *Rhynchonella corallina*, followed in regular succession by the Oxford grit and marls.

This traverse has been given in greater detail because it appears to be a very important one, not hitherto noticed or described, and serves for a term of comparison between the series of the Aube and Haute-Marne and that of the Yonne. The thicknesses given by Leymerie must be maxima; but the succession he gives is well made out. It is obvious that he reckons the whole down to the Diceras-beds to belong to his Astartian: the first-named is his "nodular white limestone," though *none* of his lists of fossils contain *Diceras*; and the underlying beds observed in the valley of the Laignes are his "lower coral limestone" in its three subdivisions of "compact limestone," "levique limestone," and "oolitic shell limestone." Now it has been seen that the Diceras-beds occupy the position of the shelly limestone of Clairvaux and Bayel, and hence we ought to find the true Coral Rag below in the Aube valley. Unfortunately nowhere has *Cidaris florigemma* been noted; but the false-bedded character of the "levique" limestones, and the record by Leymerie of a bed in them, at Gloire Dieu, entirely composed of Crinoids (a feature so characteristic of the Coral Rag of the Meuse), leads to the conviction that it is in these limestones we must look for the representative of the Rag, and that the coral shell-beds of the Côte d'Or must be regarded as "Coralline Oolite," so far as any separation of these can be effected. On the other hand the great development of beds below the Diceras-zone and the coralliferous character of the base leads on to what we shall see in the department of the Yonne, and show, to a certain extent, a repetition of the section in the valley of the Marne.

5. *Department of the Yonne.*—The general description of the Upper Jurassic rocks in this department is by Leymerie and Raulin, who divide them as follows (25):—

Upper Jurassic.

1. Portland limestones, 135 feet.
2. Kimmeridgian marls and limestones, 330 feet.

Middle Jurassic.

1. Astartian limestone, 33 feet.
2. White coral limestone, 300 feet.
3. Upper Oxfordian limestone.
4. Middle Oxfordian limestones or marls, 260 feet.
5. Lower Oxfordian ironstone, 33 feet.

Equally important, however, in this case are the subdivisions of M. Cotteau (34, 42), though they are not very definitely formulated. They are as follows:—

Portlandian.

1. Zone of *Pinna suprajurensis*.
2. Zone of *Ammonites gigas*.

Kimmeridgian.

Sequanian.

1. White limestones.
2. Lithographic limestones.

Corallian.

Diceras-beds.

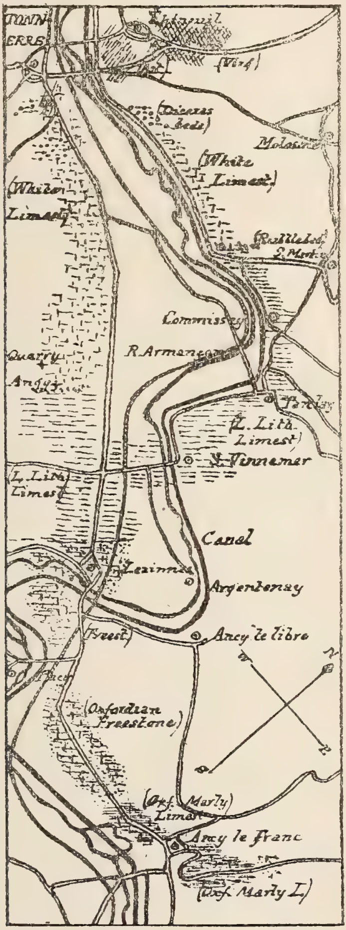
Oxfordian.

1. Zone of *Ammonites plicatilis* and *Cidaris florigemma*.

The lower portion of the Oxfordian is not brought into this scheme, the last subdivision being in another scheme made the base of the Corallian.

Two river-valleys cross this district, and the traverses made along these give a complete idea of the development of the rocks under consideration, which here attain their maximum in the lower part, where they are truly marvellous.

Fig. 9.—*Map of the Valley of the Armançon, south of Tonnerre.* (Scale 1 : 80,000.)

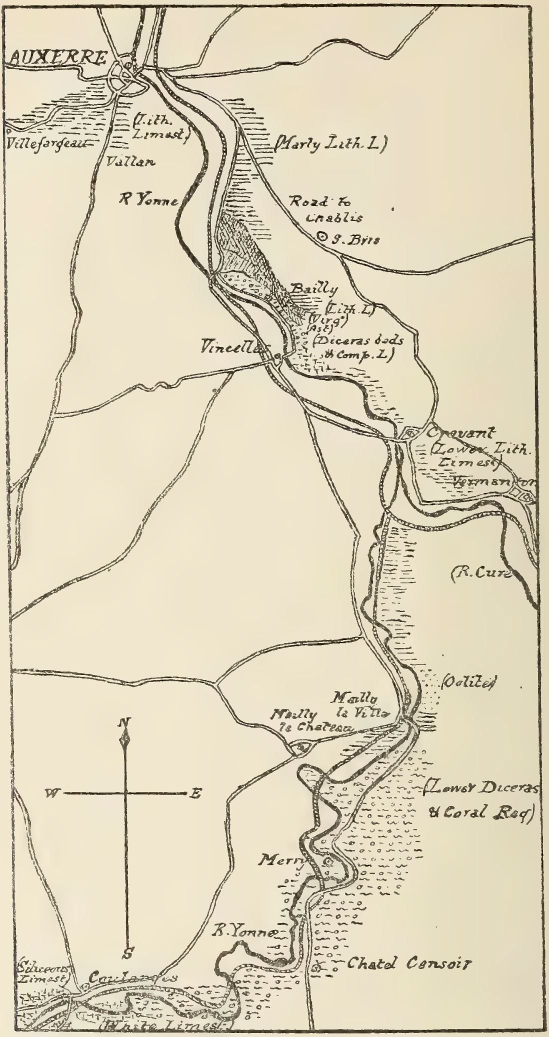


We commence with the valley of the Armançon. At Ancy-le-Franc an admirable section commencing in true Oxfordian rocks is seen above the church. Towards the base are marly beds, with only an occasional calcareous band. The fossils at once indicate the horizon, those noted being *Amm. tricristatus*, *A. Martelli*, *Pholadomya angustata*, and *Arca rhomboidalis*?. Traced upwards these marls become more calcareous and are almost limestones. They are there crowded with *Pholadomya paucicosta*, and have also *P. flabellata*, *Cercomya antica*, *Pinna lanceolata*, a *Trigonia* like *T. perlata*, and *Pecten demissus*. They become finally less fossiliferous, and are capped by shelly limestones. This series may be traced with the same character westwards to a great roadside quarry, where a face of 40 feet of sandy limestone is worked, and so on to Pacy, where the well-known quarries have yielded many fossils, the chief of which are *Amm.* cf. *plicatilis*, *Belemnites* ? *Royeri*, *Pholadomya paucicosta*, *Myoconcha Rathieriana*, *Trigonia* cf. *irregularis*, *Pecten demissus*, *Exogyra spiralis*, and, according to Cotteau, *Ostrea dilatata*. There can be no doubt that these rocks represent true Oxfordian strata; but their relation to those in the valley of Jully has not been made out, though it is highly improbable that the latter are older, as they contain, according to Leymerie and Raulin, the characteristic fossils *Ammonites perarmatus*, *Rhynchonella varians*, and *Pecten fibrosus*, which have not been found here. The numerous changes thus observed in the character of the rocks which underlie the Corallian must be due either to an unconformity or to a very variable development of the Oxfordian strata; but we can hardly accept the arrangement of the strata by the above-named authors, who place the beds with *Rhynchonella varians* as the Lower Oxfordian, while those at Ancy and Pacy are considered to be one facies of the Middle Oxfordian, of which the other facies is the Coral Rag, to be noted presently at Merry-sur-Yonne and elsewhere. The next succeeding series in this district is a mass of lithographic limestones, tending to split into thin plates, and for the most part unfossiliferous. Here and there, however, in its mass are fossiliferous zones, apparently the representatives of strongly characterized beds further to the east. The lowest of these has not actually been met with; but it is very instructively described by Cotteau (43), as seen in the neighbourhood of Gland, where the following upward succession is determined:—(*a*) ferruginous Oxford clay; (*b*) sponge-bed; (*c*) limestones of Pacy; (*d*) rubbly limestone; (*e*) coral-bed, with *Pecten subarticulatus* and *Cidaris florigemma*; (*f*) lithographic limestones; (*g*) coralline limestone of Tonnerre. It is impossible not to see in the beds *e* and *d* the continuation of those of Vannage and the Côte d'Or, the succession being perfectly consonant to what we might expect. There are, however, other bands in the lithographic limestones nearer the summit, one of which is seen on the roadside west of Commissey, associated with a rubble-bed; another occurs close to the village of Angy (below the white limestone), where it was seen by Hébert (31), and considered to be a junction-bed between the Corallian and Oxfordian, though lying upon one great mass of lithographic limestone and covered by another. The commonest fossil of this series is *Rhynchonella corallina*. This portion, though, being more lithographic, it is less clearly characterized, will occupy the place of the compact and "levique" limestone of Riceys, if we find above it the representative of the Diceras-beds.

Above the lithographic limestones comes an enormous mass of white chalky limestone, seen on the right bank of the Armançon between Commissey and Tonnerre, and on the left bank at the well-known quarries of Angy and Tonnerre. The limestone of Angy is celebrated for its fossils, which occur in profusion and in admirable preservation. A face of 50 feet is worked, the rock being more sandy towards the base, and having masses of *Septastræa*, large *Montlivaltiæ*, *Trichites Saussurei*, *Diceras* sp., *Rhynchonella matronensis*, *Terebratula maltonensis*, and *Cidaris*, apparently not *C. florigemma*. As this is the "White coral limestone" of Leymerie and Raulin, we find it credited with 300 feet of thickness. This it might well be judged to have from the hills in which it occurs; but it is not again well seen till the great quarries near Tonnerre are reached; and here it has a 60-feet face, which contains a different and higher portion, remarkable for the great masses of banded flints which lie more or less in lines. These are Nos. 7 to 15 of Cotteau's section (34) and contain many unusual Echinoderms. We here also find the overlying rocks, which are, first, a solid block of 10 feet with rolled nodules and a few specimens of *Diceras* and *Rhynchonella pinguis*, and next some nodular and coralliferous beds. The corals are rolled and not *in situ* (No. 56 of Cotteau). Next comes a coarse oolite, and then another rubbly bed with massive corals, *Rhynchonella pinguis*, *Terebratula Leymerii*, and many other fossils, but no sign of *Cidaris florigemma* (No. 24 of Cotteau). On the opposite side of the river no good exposures of the white limestones occur at present; but Cotteau describes an important quarry, called "Voceuses," which contains, amongst other fossils, *Cardium corallinum*, *Glypticus hieroglyphicus*, and *Cidaris florigemma*. The upper part, however, is seen about 2 kilometres south of Tonnerre, containing but few fossils, but in parts composed of white rubble of exactly the usual character. It is plain, therefore, that all this mass must be considered a development of the Diceras-beds of Riceys, in which the peculiar character is less regularly marked, and the fossils are therefore somewhat different. On this side of the river other quarries show rubbly beds above, then sublithographic stone, and then another rubble-bed full of *Terebratula Leymerii*, which Hébert (31) regards as the base of the Astartian, though we have seen near Gyé that there may be several such overlying each other. Above comes a coarse brown oolite, which may, or may not, be the same as that seen on the west of the river. In any case the sequence on this side matches very well with the Gyé section, in which also rubbly beds with *T. Leymerii* were overlain by oolite. The upward succession is of no particular interest here; but the lithographic stones which overlie the oolites gradually become more chalky, and finally yield *Exogyra virgula* and *Pholadomya acuticosta*, beyond which the beds have not been traced, as they are better known near Auxerre.

The next traverse is up the valley of the Yonne, where it is best to commence with the uppermost beds. It has been seen that

Fig. 10.—*Map of the Yonne Valley south of Auxerre.*
(Scale 1 : 240,000.)



Cotteau divides the "Portlandian" rocks into two groups, the upper of which is the zone of *Pinna suprajurensis*. This is very well seen in the neighbourhood of Auxerre, and, like all these upper rocks, is more fossiliferous as we go west. After the splendid monograph by Loriol and Cotteau, it is superfluous to quote the fossils, the great majority of which come from the upper portion. We need only compare the series with those seen before. In the valley of the Yonne there is no oolite to compare with the Bure Oolite; but the fossiliferous beds here correspond in character and fossils to the limestones of Trannes, and therefore to the "carious limestones." It is also possible that, from the unevenness of the Neocomian denudation, portions of the higher zone, or "spotted limestones," may be represented, as at Villefargeau; but the series is certainly incomplete in its upper part; and the question of any passage here into the Neocomian, which De Loriol propounds (42), cannot possibly be seriously raised. The lower portion of the "Portlandian" rocks is well seen on either side of the Yonne valley, where quarries occur with a 40-feet face of a soft chalky limestone with intervening beds of marl, in which there is occasionally a lumachelle of *Exogyra virgula*. Some of the marls contain abundance of *Thracia depressa*; and the other fossils noted were *Amm. gigas*, *A. suprajurensis*, *A. Gravesianus*, *Plectomya rugosa*, *Cyprina Brongniarti* (in another quarry), and *Pinna granulata*. These beds correspond in position to the lithographic limestones of Joinville. The beds in this locality have a gentle rise to the south, and the sequence can be well taken up again near Vincelles and Bailly. The tops of the hills here are occupied by the "Portland" limestone, beneath which come earthy fossiliferous limestones with large examples of *Terebratula subsella* and *Pholadomya multicosta*, which graduate downwards into marls full of *Exogyra virgula*. The Astartian beds are not well seen in any section; but they consist partly of solid and partly of rubbly limestones, with bands of *Terebratula Leymerii*, containing *Plectomya rugosa*. Towards the base the beds become oolitic, then nodular, then bedded; then comes a 16-feet mass of brownish oolite* with *Rhynchonella pinguis*, then 2 feet of solid limestone. Below this comes an 8-feet block of solid character, here and there containing the peculiar pisolite of the Diceras-beds, which forms the cap to a mass of white limestones, varying from oolitic to chalky, and containing *Ceromya excentrica*, *Homomya compressa*?, *Nerinæa pseudospeciosa*?, *Corbis gigantea*, *Trigonia Etalloni*, *T. variegata*, *Pecten Tombecki*, and, perhaps, *Cidaris florigemma*. The series thus described is obviously identical with that seen at Tonnerre, with the exception that there are no beds of rolled corals over the Diceras-beds. The white limestones extend some way to the south, where they are succeeded by lithographic limestones. The basement has not been seen, but is stated by Cotteau (42) to contain *Rhynchonella corallina*, *Terebratula humeralis*, and *Pholadomya paucicosta*. At Mailly-la-ville are seen some 20 or 30 feet of very flaggy beds, succeeded by 12 feet of oolite, and then a development of the most extraordinary kind, totally different from any thing seen before and of great interest. Along the banks of the Yonne are fine hoary cliffs, composed at first of a rock resembling a consolidated calc tuff, without any stratification and weathering into peaks; the fossils are not so numerous as might be expected, though *Pecten articulatus*

* Above this bed, Hébert (21) draws the line between the Coral Rag and the Kimmeridge Clay.

and *Rhynchonella corallina* were noted. On the same level these change into Diceras-beds of characteristic material, with many examples of that genus; and finally, at Merry-sur-Yonne, an immense cliff, 200 feet in height, and carved into fantastic shapes, frowns over the river, and is geologically an unstratified heterogeneous mass of Coral Rag, Diceras-beds, and rubble all together. Huge masses of *Thamnastræa*, delicate branches of *Caryophyllia*, and fan-like growths of *Thecosmilia* here and there ornament the surface; and in the interspaces innumerable specimens of *Diceras*, *Cardium corallinum*, stout spines of *Cidaris florigemma*, and *Trichites* a foot in length are crowded together. It is the finest example of a Coral Rag visible either in the basin of Paris or anywhere in England, and it is, undoubtedly, impossible to confound it with the much higher beds described as occurring at Bailly. Rocks of this description form the boundary of the picturesque valley through which the railway runs past Châtel Censoir to Coulanges. At the latter place there is an almost equally fine cliff, composed of a white limestone as beautiful as that of Angy, though apparently on a lower level, being really only a modification of the Coral Rag of Merry. Here, too, the fossils are in profusion and perfect preservation; the finest examples of various species of *Diceras* occur, associated with *Nerinæa Cottaldina*?, *N. subnodosa*, *Cardium corallinum*, *Hinnites*, *Terebratula insignis*, *Cidaris florigemma*, corals growing in reefs, and sponges. This great corallian development proves conclusively that *Diceras*, *Nerinæa*, and *Cidaris florigemma* are not always characteristic in any sense of distinct horizons, and that the lowest portion of any possible rocks which may be referred to the Corallian may be characterized by the latter species. If the series has been rightly traced in our journey westwards, these great coralliferous masses must be the grander development of the coral-growths of the base of the series in the Aube, only represented by thin bands at the base of the lithographic limestones in the valley of the Armançon. Much discussion has arisen on the correct position of these lower coral-beds. At first they were confounded with the upper Diceras-beds and supposed to be repeated by some fault (3, 6). Certain marly limestones developed at Vermanton, with a proportion of Oxfordian fossils, were, at that time, considered to belong to Oxfordian strata (9, 14). These Vermanton limestones were afterwards proved by Raulin to overlie the Coral Rag of Châtel Censoir and Merry (15); and as they were still considered by him as Upper Oxfordian, it followed that the Coral Rag below should be called Middle Oxfordian, and as such it appears in the monograph by Leymerie and Raulin quoted above (25). Cotteau, however, showed by an exhaustive examination of the fossils (16), first, that the Coral Rag was essentially "Corallian" in the usual sense, and, secondly, that the Vermanton marly limestones, though from their similar lithology they appear more closely allied to the Oxfordian than to the coral-beds below, yet, on the whole, are really Corallian. It is noteworthy that though these marly limestones are quoted in the earlier descriptions as marls "à *Amm. marantianus*" (15), the only Ammonite given in Cotteau's exhaustive list is *Amm. achilles*; of the other fossils, *Trigonia clavellata*, *Ceromya excentrica*, *Unicardium globosum*, *Phasianella striata*, and *Cidaris florigemma* are the most noteworthy. These beds are believed by MM. Royer and Tombeck to correspond to the marly beds overlying the Diceras-beds of the Haute-Marne; but by their position they must be part of the lithographic limestones which *underlie* those beds, though overlying the basal Coral Rag.

The true position of these rocks is further certified by continuing the examination downwards. On the north side of the Yonne, at Coulanges, are seen, below the beds already described, 12 feet or more of uniform compact limestones with *Gryphæa dilatata*, and then some sandy limestones, like those of Pacy, but more false-bedded and irregular, with abundance of *Terebratula bisuffarcinata*, also *Trigonia spinifera*, *Nerinæa allica*, and many corals here and there. These, which are doubtless the same as the siliceous limestone of Druies, correspond very well with what we might expect, though under a form slightly different. It is at some distance below these that the fossiliferous zone of *Amm. transversarius* occurs on the road to Clamecy.

6. *Department of Nièvre.*—The only description of the Upper Jurassic rocks of this department is by Ebray (32), supplemented by some notes in the paper by MM. Douvillé and Jourdy (60). The series is thus described by Ebray:—

KIMMERIDGIAN.

Astartian Limestone.

CORALLIAN.

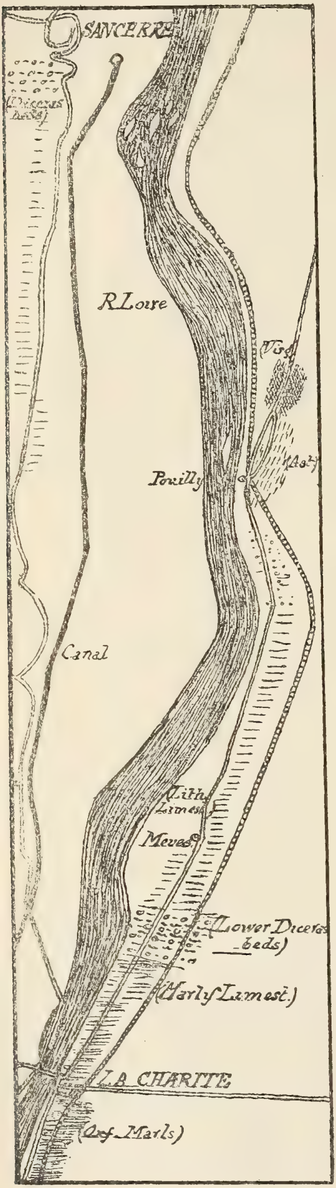
Upper Lithographic Limestone.
Oolite with small *Diceras*.
Chalky Limestone.
Lithographic Limestone.
Oolite of La Charité with *Diceras arietinum*.
Marly Limestone and Lower Lithographic Limestone.

ARGOVIAN.

Sponge-marls with *Amm. canaliculatus*.

The only traverse made in this district is along the valley of the Loire, from La Charité to the north of Pouilly. At the former place large masses of very marly limestone, having a markedly Oxfordian aspect, are worked, in which fossils are very rare, but from which *Amm. bimammatus* and *Amm. canaliculatus* have been recorded. These continue some distance; but halfway to Mèves are large quarries showing a 40-feet face of white limestone, with much of the rolled pisolitic material characteristic of Diceras-beds; and that genus here abounds, associated with *Nerinæa*. Had one never seen the limestone of Coulanges, one would, doubtless, take this for the ordinary Diceras-bed, and its low position would be a difficulty; but

Fig. 11.—*Map of the Loire between Sancerre and La Charité.* (Scale 1 : 80,000.)



there is no difficulty now in recognizing it as the tailing off of the great Coral-Rag-like mass which characterizes the valley of the Yonne, more especially as it has not been recognized on the left bank of the Loire. The whole space between these quarries and those of Pouilly appears to be occupied by barren lithographic limestones, the thickness of which it is impossible to estimate. The quarries of Pouilly are worked in a finely oolitic stone, somewhat false-bedded and containing few fossils; this must correspond to the white limestone of Tonnerre and Vincelles; and we should expect to find representatives of the Diceras-beds above: of these no evidence was found at Pouilly; but Raulin (3) and Douvillé and Jourdy (60), speaking of the same beds seen on the opposite side of the river at Sancerre, describe a regular Diceras-bed as attaining its maximum there, though dying away to the west. On the hill north of Pouilly are seen, first, lithographic limestones, then some rubbly limestones with *Terebratula Leymerii*, and at the summit the marls with *Exogyra virgula*, and no more is apparent in this direction, though higher beds might well be developed. These present no special point of interest, beyond showing the constancy of this portion of the series in contradistinction to the variability of the beds below.

7. *Department of the Cher.*—Works on this department have been published by Fabre in 1838, and Boulanger and Bertera in 1850 (10); but the most recent description is that by Douvillé and Jourdy, above quoted (60). These latter authors classify the series as follows:—

KIMMERIDGIAN.

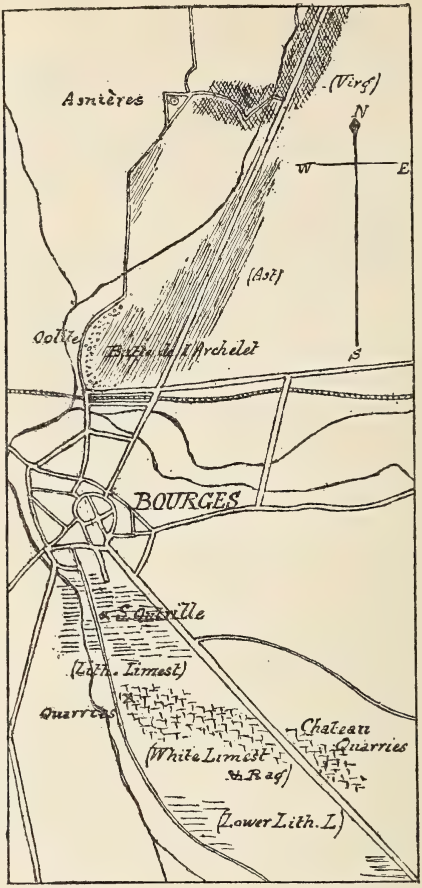
Limestone of Barrois.
Virgulian marls.
Astartian limestone.
  A. Marls and nodular limestones.
  B. Nerinæan Oolite.
  C. Fucoidal marls and limestones.

CORALLIAN.

Upper lithographic limestones with *Amm. achilles.*
  D. Limestone with *Pinna.*
  E. Compact limestones.
Chalky limestone of Bourges.
Lithographic limestones.
Sponge limestones, with *Amm. marantianus, A. bimammatus,* and *A. plicatilis.*

The first traverse in this department is in the neighbourhood of Bourges, where the succession has been already well studied and described. From 3 to 6 kilometres north of the city the Virgulian marls appear, overlain to the north by lithographic limestones, belonging doubtless to the so-called Portland, and at the hill immediately outside of Bourges the different Astartian beds are seen. The highest are earthy limestones, partially lithographic and often extremely marly. The characteristic fossils are large examples of *Ceromya excentrica* and *Pholadomya rostralis*, *Terebratula subsella* and *Plectomya rugosa*; *Natica Royeri* also occurs. The next seen are a few feet of rubbly beds, becoming very oolitic below, and more like the corresponding rock in the Boulogne area than any yet seen. It is the Nerinæan Oolite of the authors quoted, and contains *Nerinæa Desvoidyi* ?, *Trichites Saussurei*, *Terebratula subsella*, abundance of *T. Leymerii*, *Rhynchonella pinguis* ?, *Pholadomya rostralis*, and *Trigonia Baylei*, the last-named forming an interesting connexion with the rocks at Havre. The lower fucoidal marls have not been examined; but from the list of fossils quoted, among which may be noted *Mytilus perplicatus*, *Plectomya rugosa*, *Terebratula subsella*, and *Rhynchonella pinguis*, it is obvious they form part of this series. On the south of Bourges a different group of rocks occur, the upper part being lithographic, unnecessarily divided into two parts. The fossils are few, and belong to *Pinna obliquata* (a broad species), *Lucina* cf. *imbricata*, and *Terebratula* ? *tetragona*. These are of considerable thickness, and are underlain by beautiful white limestone, which betrays its origin when closely examined. It is then seen to be an exceedingly fine rubble, having here and there larger grains, and becoming almost like the Diceras-beds, to which it corresponds, and into which it is said to change at Sancerre. *Terebratula cincta* and *Rhynchonella corallina* are extremely abundant. *Lima læviuscula*, *L. rigida*, and *Corbis gigantea* were also observed. In the old quarries of the Chateau, what are probably lower beds are seen through 20 feet and more. Here are abundance of massive corals, with *Cidaris florigemma* and many shells, but fewer Brachiopoda. This, then, is the true Coral Rag as usually seen, and corresponds to the white limestones of Tonnerre and Augy. Below this the beds have not been examined, as they are stated to consist of a uniform mass of litho-

Fig. 12.—*Map of the Country round Bourges.* (Scale 1 : 160,000.)



graphic limestone over a breadth of 20 kilometres, and to show no signs of the lower limestone of Coulanges and La Charité. Boulanger and Bertera, indeed, mention a coral limestone below the lithographic, to be seen near Venesme, which may represent it; but they correlate it with beds with *Amm. hecticus,* in which case it must be Oxfordian.

In the last traverse of this range the swallowing up of all portions of this series into uniform lithographic limestones, below, at least, the Astartian beds, is carried to its maximum ; for though, near Chapelle, the white limestone of the old Château quarries is still seen to be developed, it is much diminished in thickness, and the whole of the weary way from that locality to Châteauneuf-sur-Cher, along the borders of the river, is occupied by a dreary monotony of thick-bedded, unfossiliferous, lithographic limestones. One peculiar feature, however, is to be noted. About two miles south of St. Florent, and again at Lapan, at a lower level in the series, the soil appears of a peculiar rich red colour, and at the latter locality the cause has been ascertained. Instead of the ordinary limestones there are some beds, at least 3 feet or 4 feet thick, of a crystalline irregular mass, which are suggestive of the strangely altered rock produced from corals and coral-brash; and in this mass are cavities filled with large, round, concentrically coated, limonite concretions. It is by the decay of these that the fields are covered with the red soil; and they may be regarded as the last vestiges of coral-growths, the lower of which might well correspond to the Coral Rag of Merry. As we approach Châteauneuf the limestone becomes white and more marly, but still almost, if not quite, unfossiliferous; and it is only to the south of the town that the canaliculate Ammonites set in, associated with abundant sponges and *Amm. bimammatus* and *Amm. Martelli*, on which little need be said, since they are so obviously Oxfordian. It may be noted, however, since the authors quoted place these beds as the base of the Corallian, that the first Ammonite to appear going down is *Amm. canaliculatus*; and this is far above the sponge-bed.

The valley of the Indre has not been examined; but Douvillé and Jourdy assure us that here even the white limestones are wanting, and the whole mass between the Astartian and Oxfordian consists of nothing but barren lithographic limestones, spreading over an expanse of 30 kilometres from Levroux to Châteauroux.

II. The two Charentes.

This district scarcely forms part of the Paris basin, being rather the northerly extension of the Pyrenean, and will doubtless serve as a term of comparison between the two. Nevertheless, being so close to the termination of the great range, it is more conveniently studied on the present occasion. The main question, however, of which the solution has been sought, is the age of the so-called "Portland" and even "Purbeck" beds—whether there are, in fact, in this area any rocks corresponding to those that are known by those names in England.

1. *Department of the Charente.*—The Jurassic rocks of the department have been described by Coquand (24), who divides the upper portion as follows:—

Upper Jurassic.

Purbeckian.

Portlandian.

- Carious limestone.
- Limestones with *Nucula inflexa.*
- Oolitic limestone.
- Limestone with *Cardium dissimile.*
- Sands.

Kimmeridgian.

- Virgulian marls.
- Pterocerian limestones.
- Astartian limestones.

MIDDLE JURASSIC.

Corallian.
Oolite with *Nerinææ.*
Coral limestone.
Solid limestone.
Oxfordian.
Callovian.

The whole series, as seen between Rochefoucault and Angoulême, is extremely calcareous, and no physical line can be drawn between the Oxfordian and Corallian; every portion is more compact than usual, and presents no such marked features as are often seen. The Oxfordian near Rochefoucault certainly contains coralliferous beds, and these give place to a sandy oolite. From Coquand's description it appears that the uppermost portion of the Oxfordian contains in some places such fossils as *Pecten demissus*, *P. subfibrosus*, and *Rhynchonella Thurmanni*, and in others *Amm. oculatus*, *A. crenatus*, and *A. Henrici*, and is followed by a brecciiform limestone, indicating that the Corallian here also lies on different portions and is really unconformable. The massive limestones of the last-named group occupy a wide expanse of country, but finally give way to rather rubbly limestones, doubtless the "Coral Limestone" of Coquand, which, however, scarcely forms a "Rag"; and these, again, are replaced by compact suboolitic limestones, containing *Diceras* at Touvres, and in which Coquand records several *Nerinææ* and *Cardium corallinum*, *Terebratula insignis*, and *Rhynchonella corallina*. It is obvious, therefore, that the succession, though somewhat obscure from the similarity of the rocks to each other, is the same that we have seen in the great range before the lower Coral Rag appeared. The Astartian beds are not here of any great importance, consisting of marly limestones, with *Pholadomya rostralis* and *Ceromya excentrica*. The fossils quoted by Coquand, except the *Astarte supracorallina* ("*minima*"), are not specially characteristic; and it is to be noted that he considers some beds at La Rochelle, which d'Orbigny placed in the Corallian, to be the calcareous representatives of these more marly rocks. Traced upwards, however, they become still more marly, and contain abundance of *Exogyra virgula*. Indeed this part of the series is rather exceptional; and after seeing so much limestone one's eye is refreshed by the sight of veritable clay, extending through a considerable thickness. These irregular beds may be taken up again in the railway-cuttings north of Angoulême; but the lower portion, distinguished as Pterocerian, which is to be seen some six miles to the north, at Vars, has not been examined. It appears from Coquand's description to be more than usually distinct in this district by its fossils, which include *Nautilus giganteus*, *Pteroceras oceani*, *Chemnitzia Danaæ*, *Pholadomya Protei*, *Mytilus medus*, and *Ostrea solitaria*. The Virgulian marls near Angoulême are fairly fossiliferous, the species noted as associated with *Exogyra virgula* being *Natica ornata*?, *Plectomya rugosa*, *Arca* cf. *rhomboidalis*, *Trigonia concentrica*, *T. monilifera*?, *Gervillia kimmeridiensis*, *Thracia depressa* (towards the top), *Mytilus virgulinus*, *Ceromya concentrica*, and *Pecten suprajurensis*; and to these Coquand adds *Ammonites longispinus*, *Pholadomya acuticosta*, and *Pleuromya tellina*. The rocks therefore which here underlie the "Portland" are the same that have been hitherto recognized as Virgulian, and represent the lower, or at most the middle, portion of our English Kimmeridge Clay. We are therefore prepared to find that here also the "Portland" beds are no higher than those usually so called. Now, tracing upwards the beds towards Angoulême, we find a set of rather rubbly fossiliferous limestones, containing *Pholadomya decemcostata*, *Trigonia concentrica*, *T.* cf. *Bronnii*, *Arca laura*, and *Cerithium septemplicatum*. These rocks become more sandy by degrees, and at last form a peculiarly crisp calcareous sandstone. The fossils in this sandstone, as noted, are *Pseudomelania gigantea*, *Corbis Rathieriana*, and *Avicula Credneriana*, all characteristic species of the "Lower Portland." No more is seen in this section, as the Hippurite limestone lies unconformably upon the last-named stratum. The higher beds of the district were therefore examined in the neighbourhood of Jarnac. The section at Souillac could not be verified as showing four subdivisions overlain by gypseous beds; but much oolitic stone is worked to the west of Jarnac, as far as Chassors and Nercillac, to a thickness of at least 12 feet; in this *Cyprina Brongniarti* is the characteristic fossil. From the fact of this species not being quoted, but in its place *Cardium dissimile* (only a single doubtful example of which could be found), and from the similarity of the casts of these two shells, is it possible to conclude that for the latter we ought to read the former in Coquand's lists? Still something very like the *Cardium dissimile* was seen at Nercillac, and also, as will be seen, in the Ile d'Oleron. The other fossils noted at Chassors &c. are those often accompanying *Cyprina Brongniarti*, or belonging to a higher zone, viz. *Cyprina implicata*, *Astarte rugosa*, *Pecten nudus* (= *jarnacensis*), *Cardium Dufrenoycum*, *Astarte regularis*, *Corbula mosensis*, and *Mactra insularum*. Overlying these near Jarnac are more flaggy beds, with many small oysters at the base. Comparing this with the more complete development in the Haute-Marne, the beds here shown belong obviously to the zone of *Cyprina Brongniarti*; and as several of the fossils indicate at least the upper part of it, though the gypseous beds above give no clue to their age, and we are therefore left without proof in this district of the equivalents of the vacuolar oolite representing the true Portland, it is probable that such beds, though under a somewhat freshwater condition, are actually reached, being represented by the so-called "Purbecks."

2. *Department of the Lower Charente.*—The rocks in this department, originally studied by d'Orbigny (14), have since been more fully described by Manès (17), who divides them as follows:—

Portlandian, 280 ft.
- Gypseous beds.
- Lumachelle limestones.
- Tabular compact limestones.
- Alternations of compact limestones.

Kimmeridgian, 260 ft.
- White chalky limestone.
- Marls with *Exogyra virgula.*

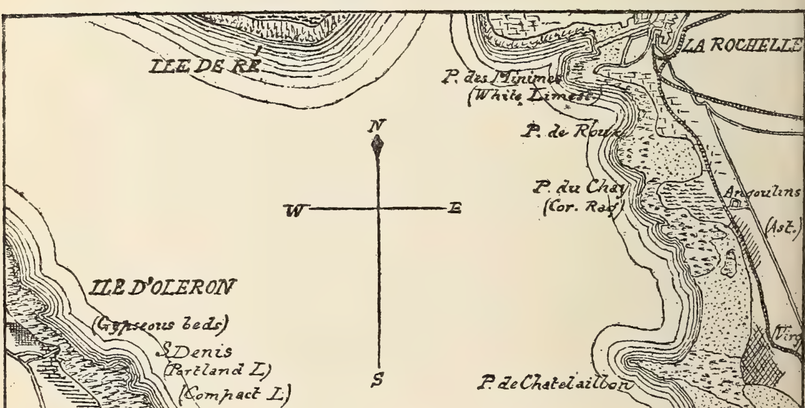
Corallian, 330 ft.
- Coral limestones.
- Limestone with *Nerineææ.*

Oxfordian, 550 ft.
- Shaly marls.
- Clays and marly limestones.

Whether the rocks in the Lower Charente are really different from those in the Upper, or whether their exposure in the sea-cliffs gives a better opportunity for judging differences, certain it is that in the neighbourhood of La Rochelle one is immediately aware that one is studying the development in a new basin, and things are changed. If, in fact, we examine the lists of d'Orbigny as given in his 'Prodrome,' we find that out of 222 Corallian species from this locality, no fewer than 90, or more than 40 per cent., are peculiar, while only 80 occur in any of the localities yet studied.

The Oxfordian strata are of particular interest as occurring at Marans, whence the name of *Ammonites marantianus* is derived, which indicates that we should expect the overlying "Limestones with *Nerinææ*" to belong to the true Corallian series. The lower portions of these occur on the north side of La Rochelle; but the upper portion is the more fossiliferous, and occupies the first two headlands to the south, viz. the Point des Minimes and the Point de Roux. Here they are very marly, with beds of limestone crowded with cavities formed

Fig. 13.—*Map of the Coast round the Pertuis d'Antioch.* (Scale 1 : 240,000.)



by fossils which have decayed, leaving their exteriors perfectly moulded. The most abundant fossils are some large curved *Montlivaltiæ* (*M. subnigra*, d'Orb.?), various peculiar *Nerinææ*, small *Cerithia*, *Mytilus pectinatus*, *Trigonia aculeata*, d'Orb., *T. Tombecki*? (*T. Meriani* of d'Orbigny, but not that species), and *Astarte bicostata*. Thus the common fossils are the peculiar ones, and one must fall back upon more detailed lists of rarer fossils. Amongst those quoted by d'Orbigny, the most important for correlation are *Belemnites Royeri* (probably from the lower portion), *Ammonites achilles*, *Natica grandis*, *N. hemisphærica*, *Turbo princeps*, *Cardium corallinum*, *Mytilus acinaces*, *Lima læviuscula*, *Avicula polyodon*, *Pecten subarticulatus*, *Terebratula insignis*, and *Hemicidaris crenularis*. None of the others having a contrary tendency, it is plain that in the great mass composing this series we have represented the shell-limestone usually included in the Corallian, up to and including the Coral Rag itself; though *Cidaris florigemma* does not appear to flourish here, and the corals are not Astræan. Passing south towards higher beds, we find some more marly limestones with *Pholadomya Protei* and *Pinna obliquata* not uncommon. If the latter shell may be trusted to keep to a single horizon, it should represent the lithographic limestones overlying the chalky limestones of Bourges. However, at the next point, Point du Ché, a fine development of a Coral Rag is seen. This is credited with more than 200 feet by Manès; but as the next series named is the Virgulian marls, it is obvious that the Astartian beds are included in this. The cliffs have a height of 30 feet to 40 feet; and all is apparently Coral Rag, though on a higher horizon than usual. Fossils like *Arca tetragona*, *Lima verdunensis*, *Terebratula*, are abundant, with spines of *Cidaris*; to which may be added from d'Orbigny's list *Nautilus giganteus*, *Nerinæa Mandelslohi*, *Pinnigena Saussurei*, *Diceras arietinum*, and *Rhynchonella pinguis* ("*inconstans*").

This portion of the series may therefore fairly be placed on the horizon of the Diceras- or Supracoralline beds, like the far-off coralliferous deposits at Novion; and it corresponds with the uppermost portion of the Corallian of the Charente, as described by Coquand. At the cliff near Angoulins, very little to the south of the Point du Ché, the last of the rubbly limestones, with *Lima læviuscula* and *Ostrea* cf. *gregaria*, is seen occupying the base, overlain by about 5 feet of marly beds with *Pholadomya Protei* and *Ceromya excentrica* of large size, and then a hard limestone band with many fossils, amongst which are corals, *Pecten striatus*, and *Cidaris Smithii*?, but also a great abundance of *Terebratula Leymerii*. The presence of this last species would indicate Astartian beds, which are otherwise unrecognized; and these are doubtless the beds to which Coquand alludes when he says d'Orbigny has placed them with the Corallian on account of their being calcareous. As noted, however, by Hébert (54) only nine of the species found here are common to the Corallian beds at the Point des Minimes. In the same paper we learn that the marls of Châtelaillon, which show the upper succession, contain *Amm. cymodoce*, *Natica hemisphærica*, *Pteroceras oceani*, *P. Ponti*, *Mytilus jurensis*, *Ceromya excentrica*, *Thracia suprajurensis*, and *Pinnigena Saussurei*, and are therefore very fair representatives of Pterocerian beds, especially when compared with those at Havre. Neither these beds nor the overlying Virgulian marls could be specially examined.

The so-called Portland beds, however, of the Ile d'Oléron demand particular attention. As in the Charente department, the upper part is gypseous; but M. Manès does not on that account call them Purbeck, but classes all with the Portland. The beds are well displayed along the cliffs and shore of the island on either side of the harbour of St. Denis. The lowest beds seen are (1) massive blue calc grits, which stand out as reefs at low tide on the north of the harbour, and are broken up and stacked on the roads. These contain *Ammonites Gravesianus* and *Trigonia* cf. *concentrica*. They are succeeded by many other beds, forming scars, which are better seen on the south of the harbour, though the succession may not be perfect. The lowest beds seen here are (2) marly limestones and grits, of unknown thickness, more than 4 feet; next is (3) blue sandy marl, 3 feet; (4) hard blue sandy beds, with circular fucoid markings, with *Mytilus Morrisii*, *Trigonia concentrica*?, *Cardium morinicum*, and *Exogyra nana*, 2 feet; (5) earthy marls, 1 foot; (6) solid calcareous block, with *Cyprina Brongniarti* (broad var.), *Lucina portlandica*?, *Pecten suprajurensis*, *P. jarnacensis*, *Cardium dissimile*, and *Astarte rugosa*?, 1 foot; (7) alternations of limestones with lumachelles of *Exogyra nana* and earthy beds with *Cardium Morriseum*, 6 feet; (8) thin-bedded limestones, with shale and clay, 10 feet. In the cliffs on the north side, separated from the low-water rocks by masses of blown sand, are beds which must succeed the above, but perhaps not immediately. These are (9) alternations of thin-bedded limestones and black sandy marls, with gypsum, possibly the continuation of (8), 12 feet; (10) black and white sandy clays, no fossils, 20 feet; (11) thin-bedded and laminated clays, $3\frac{1}{2}$ feet; (12) black laminated clay and sandy limestones, 8 feet; (13) purple lithographic suboolitic limestones in thin beds, the uppermost when weathered becoming a vacuolar oolite, and containing masses of shell-fragments, all undistinguishable, unless one is a flattened *Cardium dissimile*?, 2 feet. Above this are still some white chalky fragments; but no more is seen. Here, again, therefore the same argument holds as for the neighbourhood of Jarnac. The fossiliferous beds cannot be lower than the zone of *Cyprina Brongniarti*; and the higher beds must in all probability represent true Portland rocks. The occurrence of *Cardium dissimile* is especially noteworthy. It is found near the top of the series; and in no other locality does it occur lower than the true Portland. If the rocks which contain it be of such an age, we must place the overlying gypseous beds in the same category, unless we choose to call them Purbeck. This we should not be justified in doing unless we had the *whole* of the Portland limestone here, which is improbable.

III. Normandy with Orne and Sarthe.

1. *Department of the Orne and Sarthe.*—It has not been possible to examine the feeble development of the Upper Jurassic rocks in the narrow strip which leads northwards from Le Mans to Normandy. We may note, however, that Hébert (21) shows that the Oxfordian beds with *Amm. perarmatus* and *A. cordatus*, which he calls "Middle Oxfordian," consist of sand and calcareous grits; while the "Upper Oxfordian," with *Trigonia perlata* (? "*clavellata*"), *Pholadomya decemcostata*, *Perna mytiloides*, and *Gervillia aviculoides*, is marly. This is a succession very like that to be seen near Trouville. Near Bellême are said to be seen, over this, calcareous grits full of *Trigonia Bronnii* (surely not the Supracoralline species!); next some oolitic limestones, with large *Astarte mysa* (? = *A. ovalis*). Next come pisolites with *Nerinææ* (probably equivalent to the limestones of Trouville and Osmington); and finally, at some distance above, come Diceras-beds, containing *Cardium corallinum* and *Corbis gigantea*, which have not been matched further north. These Diceras-beds elsewhere in the neighbourhood are said to be covered by an oolitic coral-limestone, very irregular on its surface. This is succeeded by marls and marly limestones, with *Ostrea deltoidea* and several other of the lower fossils of Havre, such as *Trigonia Meriani* ("*muricata*"), *Cyprina cornuta*, and *Rhynchonella inconstans* (?); and after a very slight interval come the Virgulian marls. These facts are very instructive, as showing, amidst a general development similar to that of Normandy, some of the peculiar features, *e. g.* the Diceras-beds, of the great southern range.

2. *Normandy.*—In studying this district it will be well to go, in the first instance, to the coast, because there the section is complete and has been described by several authors. The earliest description was that by Caumont (1), who gives some account also of the interior, and recognizes the following subdivisions:—(1) Kimmeridge Clay, (2) Glos sand and Blangy limestone, (3) Coral Rag, (4) Oxford Clay. A later and more complete description of the coast only is by Hébert (28), who gives very detailed sections, and divides the rocks studied into (1) Coral Rag, (2) Upper Oxfordian, and (3) Middle Oxfordian. A further description of the higher rocks was promised at the time, but has never yet seen the light. The continuation of the series on the opposite side of the Seine, at the Cap de la Hêve, has been described by Dollfus (30), who recognizes three portions of the Kimmeridgian, as (1) Ammonite-clays, (2) Pteroceras-marls, (3) Trigonia-clays and limestones; and by Lennier (49), who gives a detailed section of the beds at the Cap de la Hêve, and thence to Octéville.

In the examination of this section the English geologist is at once struck with the extraordinary resemblance of the series to those at Weymouth and Osmington. So close indeed is it, that almost bed for bed can be recognized; and the whole becomes therefore an admirable term of comparison between the French and English rocks,

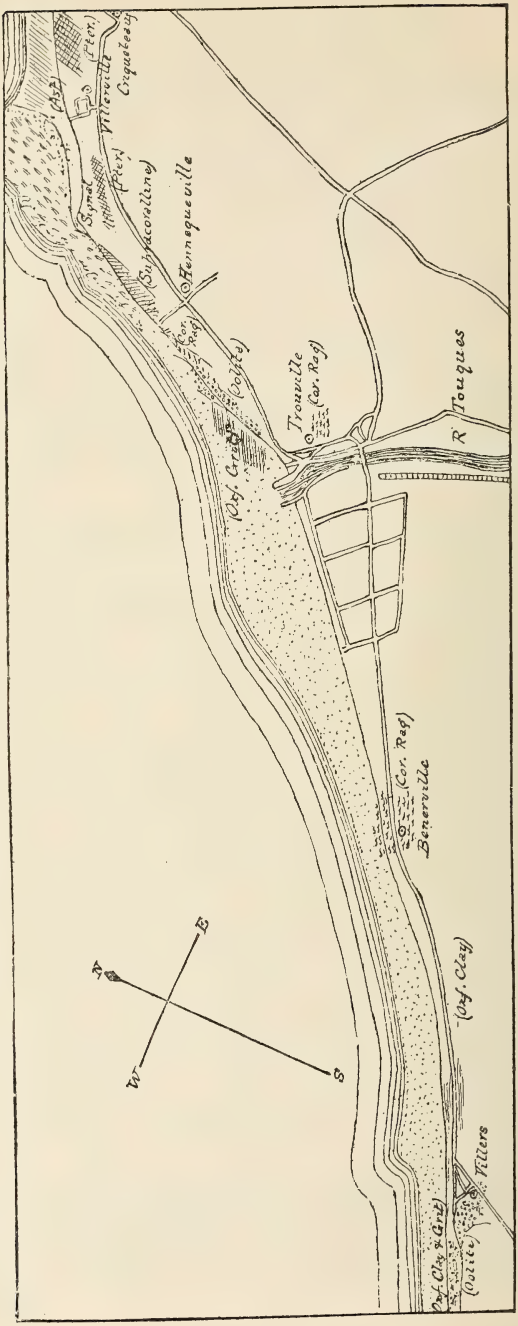


Fig. 14.—*Map of the Coast near Trouville.* (Scale 1 : 80,000.)

if only the development in each country could be correlated respectively with these.

The cliffs of Auberville are mainly composed of fossiliferous Oxford Clay (known as Argile de Dives); and Caumont's section, in which he indicates the presence of Coral Rag, Upper Calcareous Grit, and Kimmeridge Clay beneath the Cretaceous rocks, is quite deceptive. Hébert, however, gives details of 33 beds seen in the central portion of the cliff, all referred by him to the Middle Oxfordian. His lower 19 divisions, comprising 195 feet of clays, with various bands of nodules, would correspond to the Weymouth Oxford Clay. To within 60 feet of the top this is pure clay, and bands towards the base are very fossiliferous, the horizon being indicated by such fossils as *Amm. Lamberti*, *A. arduennensis*, *Turbo Meriani*, *Modiola imbricata*, *Nucula ornata*, and *Rhynchonella varians*. These are succeeded by numerous bands of ferruginous oolite, scattered in the midst of the clays through a thickness of about 20 feet, after which the clay still continues for another 40 feet. The whole of these have *Ostrea dilatata* in great abundance. One might be tempted to regard the ferruginous bands as corresponding to the Nothe grits; but the latter are better represented by the mass which succeeds the Oxford Clay. This commences with a bed of oolitic grit of about 5 feet, then more clay for 5 feet, and then 12 feet of strong ferruginous oolite and grit, which is marly in parts, and has a lumachelle of small oysters at the top. These beds are very constant: they may be traced all along the cliff of Auberville as far as Villers, and may be seen again at low tide on the shore east of Trouville. At this last locality the lower beds contain *Ammonites plicatilis*? and *Pecten fibrosus*. The intervening clays make no show; and the upper part are dark-brown oolitic grits, exactly similar to those at Osmington, crowded with large *Gervillia aviculoides*, *Trigonia perlata*, and *Pecten fibrosus*; towards the top is a bed of *Serpula tricarinata*, and, finally, a regular Trigonia-bed like the lower one at Osmington. These are the beds Nos. 20–29 of Hébert's Auberville section, and Nos. 2 and 3 of his Trouville section, which is rather differently described. The principal fossils noticed, besides those mentioned, were *Astarte ovalis*, *Cerithium muricatum*?, *Unicardium globosum*, *Pleuromya tellina*, and *Exogyra spiralis*. The next portion of the series corresponds to the Nothe clays. It consists at Auberville of blue clay at the base with hard bands and fossils, and at the top of purple unfossiliferous clay, making a total of 6–8 feet. At Trouville the base is darker, and contains lumachelles of *Exogyra nana*. There is a hard blue calc-grit with fucoidal marks at the top, which, from its position, may be taken as the representative of the Bencliff calc-grit. These are Nos. 30–32 of Hébert's Auberville section, and apparently No. 3 of his Trouville section, though the grit is not noticed. Above these come about 6 feet of alternations of clays and ferruginous oolitic bands at Trouville, scarcely recognizable at Auberville, in which *Exogyra nana* and *Pecten fibrosus* are still abundant, with *Trigonia corallina*, *Pecten lens*, *Lucina Moreana*, and *Pseudodiadema* sp. These must be reckoned with the succeeding beds, which are perfect representatives of the Osmington oolites. Like these same oolites as seen at Weymouth and Osmington, they are in one place more compact than in another. They are large-grained and more or less rubbly at Trouville, especially towards the base, and in alternating bands up to the top, where they are capped by a pisolite full of *Nerinææ*, forming a very characteristic horizon. At Auberville they are likewise very oolitic towards the base, and this is the only part of them which is anywhere seen in the cliff; but as they have a dip towards the S.E., the upper portion is exposed in stream- and road-sections near Villers, beneath the Cretaceous strata, and is seen to consist of a fine massive oolite, perhaps as much as 20 feet in thickness, with scarcely any fossils except *Pecten qualicosta*. The more pisolitic beds, however, are crowded with fossils everywhere, the most abundant species being *Echinobrissus scutatus*, *Opis Phillipsii*, and *Cerithium muricatum*. Other fossils are *Chemnitzia heddingtonensis*, *Pleuromya Voltzii*, *Nerinæa elongata* (or ? *fasciata*), *Phasianella Buvignieri*, and *Lima subantiquata*. Above this, at Hennecqville, are seen blackish oolitic beds, of no great thickness, alternately hard and soft, with *Trigonia clavellata* and *Gervillia aviculoides*, which may be paralleled with the Trigonia-beds of Weymouth. The series above is variable, as usual with the Coral Rag. At Hennecqville there are 18 feet of dark unfossiliferous clay, rather sandy at the top, and rapidly changing in character towards Trouville, where it is almost concealed. Hébert mentions that at Villers, in some locality which is now inaccessible to observation, marls and limestones with *Cidaris florigemma* succeed the oolites. Above this clay at Hennecqville the beds become oolitic again through 12 feet, and very similar to those below*, most ferruginous at the base, and cavitary towards the top by the decay of fossils, the most abundant of which here are *Opis corallina* and *Nerinæa fasciata*?. There are also *Cerithium muricatum*, *Littorina muricata*, and *Isodonta Deshayesia*. The capping of this mass for about 1 foot at Hennecqville is a ferruginous suboolitic limestone, full of fossils, especially *Cidaris florigemma* and some corals—also *Nerinæa imbricata*, *Opis corallina*, *Cypricardia isocardina*, *Pleuromya tellina*, *Pecten vimineus*, *P. qualicosta*, *Lima proboscidea*, *Exogyra nana*, &c. This is the only representative of Coral Rag at this spot, where the clay is thick; but as we pass towards Trouville all that lies above the Osmington Oolite rapidly changes its character and becomes more calcareous. The last exposure towards the town shows massive limestones with rubbly *Cidaris-florigemma* beds towards the top, through an aggregate thickness quite as great as at Hennecqville (31 feet); and in a large quarry in the town are seen beds which must be the representatives of this portion, though very dissimilar. Here at the top is a rubbly coral-reef mass, utterly irregular at its base, lying in

* This clay and oolite are so similar to the clay and oolite below, that it is possible one may be deceived by slips, and they may be actual repetitions. At no place can the beds above the Lower Oolite be *certainly* determined; but at Trouville they actually lie at a considerable depth below the beds with *Cidaris florigemma*, which latter are underlain by a more compact limestone. If there be a slip, it is a very uniform one and parallel to the face of the cliff.

great depressions of the subjacent limestones, and at places 20 feet thick. The corals are *Thamnastræa* and *Calamophyllia*; and *Cidaris florigemma* and *C. Smithii* also abound, with *Littorina muricata*, *Pseudomelania Coquandi*?, *Natica corallina*, *Pholadomya Tombecki*, *Corbicella* sp., *Ostrea gregaria*, and *Acrosalenia* sp. Underlying this are 20 feet of shelly oolites, in which the fossils are badly preserved, *Trigonia corallina* (?) and *Opis corallina* being the chief noted. Below these again are 4 feet of rubble (with *Hinnites velatus*), and then 3 feet of oolite. This quarry does not appear to have been described before; but it is of considerable importance as showing the rapid development of coral-growth, since, not a mile away, only the feeblest representative is seen in the cliff. In the other direction, towards Auberville, however, it becomes perhaps of still greater importance; for at Benerville admirable coral-masses are developed, and slip down onto the sea-shore. These are of considerable thickness, and contain a crowd of all the usual Rag fossils, as at Trouville; they are underlain by oolitic stone and unfossiliferous clay. The whole mass, however, is out of place; and no stratigraphical data are obtainable. Hébert does not notice this, though he describes the clay onto which it has slipped as crowded with Oxfordian fossils. At Villers only fragments are now visible; and, according to Hébert's section, the reef is dying out; for he indicates only about 16 feet of limestones and marls, including the *florigemma*-rag. From the position which this rag occupies with relation to the beds below, and, as will be seen, to the beds above also, it follows that it occupies the place of the "Sandsfoot Clay," and possibly of the lowest bed also of the "Sandsfoot Grit," many of the fossils of which are common to it. It is, however, so intimately connected with the subjacent oolites, as to make it difficult to range the two in different subdivisions of the geological series.

Above the representative of the Coral Rag at Hennecqville, where alone any higher beds are seen on the coast, come calcareous grits and sands, admirably representing (as will be seen) the Sandsfoot-Castle beds. For the lower 15 feet they are marly sandstones with *Pseudomelania striata* and a narrow *Nerinæa*; then comes a hard calcareous grit, called by Caumont the Blangy limestone, from its being worked at a village of that name; and above this a series of beds varying very much in thickness, containing, towards the base, white hummocky calcareous grits with intervening yellow sand and beds of *Trigonia muricata*; then fucoidal grits and sands, with great masses of black flints, dying out to nothing (one was noticed 3 feet thick by 16 feet long); and at the top honeycombed masses of soft and hard sandy beds, the cap being especially hard, and serving as a ledge on which the overlying clay appears to rest conformably, though it has doubtless slipped down and covered the intervening beds seen further east at Villerville, and blocks of which here strew the strand. The whole thickness of these is nearly 40 feet; and they contain also *Ammonites varicostatus*, *Chemnitzia delia*, and *Pinna granulata*.

So far the section, instructive both by its resemblances and by its differences when compared with that at Weymouth, has been described before; but the succeeding beds which connect it with the section at Havre, and complete the similarity of the whole to the English series, appear to have escaped description. So completely, indeed, have they done so that Hébert (see 41) states that the Trigonia-grits of Havre are separated from the base of the Kimmeridge Clay by 160 feet of marls which overlie the Corallian beds at Hennecqville, these 160 feet being obviously the overlying clays which have slipped forward and *covered* the grits which are seen *in situ* further on. Though of considerable thickness, they have been subjected to so much disturbance that they make but little show even when exposed, as on the shore on either side of the village of Villerville. First, overlying the last-named grit of the Corallian series, which forms an admirable base line, are about 8 feet of marls; and next a series of remarkable hard beds filled with small shells. These extend through about 4 feet, and are flaggy; some of the bands are crowded with a small *Cerithium*; others have abundance of *Astarte supracorallina*, *Cardium delibatum*?, and *Exogyra bruntrutana*. Next come perhaps 10 feet (more or less) of grey marls; over which lies, apparently *in situ*, a gritty bed full of black pebbles; then more marls, 8 feet to 10 feet; and finally, in this locality, 3 feet 6 inches of oolitic ironstone and associated marls with *Pecten midas*. All these are seen together to the west of Villerville. On the east side, presumably the same oolitic ironstone bands are seen in slipped masses on the strand, followed in an upward direction by flaggy sandy marls full of *Pleuromya Voltzii*; then some more marls, 8 feet; next a bed of small oysters (*Exogyra nana* or *bruntrutana*), 1 foot; next 3 feet of soft marl; and then the remarkable sandy grit with *Trigoniæ*, so well known at Havre and Weymouth, about 1 foot in thickness; above which come about 4 feet of clays with two bands almost made of *O. deltoidea*; and finally the ordinary completely argillaceous Kimmeridge Clay, which so often slips down and masks the beds just described. If any one compares this section with that at Sandsfoot*, he will see an almost exact identity, in which the ironstone, the lumachelle, and the Trigonia-grits hold their relative positions and almost their distances—the only difference being that the *O.-deltoidea* beds appear here to lie, as they are said to do at Havre, *above* the Trigonia-grits instead of below. The fossils also are equally characteristic, those noted being *Ammonites cymodoce*, *Belemnites nitidus*, *Littorina pulcherrima*, *Natica eudora*, *Pholadomya* "*Protei*," *Opis angulosa*, *Astarte Michaudiana* (called *ovata* before), *A. trigonarum*, *Cyprina Constantini*, *Cyprina cyreniformis*?, *Trigonia Meriani*, *T. muricata*, *T. papillata*, *Mytilus pectinatus*, *Pecten midas*, *P. suprajurensis*, *P. minerva*, *Gervillia kimmeridiensis*, *Serpula gordialis*, *S. quinquangularis*, *S. tetragona*, and *Montlivaltia Lesueurii*. The presence of this latter fossil is of interest as showing that coral-growth had not died out here; for it must be to the lower portion of this series that the "Upper Coral Rag" seen in Ringstead Bay must be

* Q. J. G. S. vol. xxxi. p. 241, and vol. xxxiii. p. 270.

referred, which is, at the same time, proved to be on a much higher horizon than the ordinary Coral Rag of Normandy.

The section thus concluded at Villerville can be perfectly taken up on the other side of the estuary at Havre; for the "Trigonia-grit" at the former is simply the continuation of the "Calcaire à Trigonies" at the latter, of which the fauna has been so admirably illustrated by Dollfus. These, including the associated marls and other hard bands, up to and including the grey clay over the fossiliferous grit, are therefore the Kimmeridge passage-beds, as was ascertained by Waagen (35). It is also obvious that by their stratigraphical position and by many of their fossils they represent the Astartian beds of the rest of France *. Of the overlying beds at Havre little need be said, since their position cannot be otherwise than clear. The beds included between No. 4 and No. 14 of Lennier's section, the latter being a hard band with many gasteropods, represent Dollfus's "Marne à Ptérocères," and the basal portion of the Lower Kimmeridge of Weymouth. In Normandy there is certainly much more reason for establishing a "Pterocerian stage," since *Pteroceras Ponti* is a very common fossil both at Villerville and at Havre, and has associated with it a sufficiently distinct fauna. It is therefore perhaps only due to the imperfect searching of the beds at Weymouth that a similar fauna has not been discovered there. Of the fossils in Dollfus's list which are found only in the Pterocerian beds, the following occur in the Lower Kimmeridge of Weymouth—*Amm. decipiens*, *Pleuromya tellina*, *P. donacina*, *Pholadomya acuticosta*, and *Ostrea solitaria*. Only one of these is at all characteristic; and that is *Phol. acuticosta*, which, as we have seen, is a constant species in the Virgulian marls, whether these are divisible into two parts or not. In fact the fauna consists almost exclusively of Myacidæ, Gasteropods, and Echinoderms, of which the latter two groups are so remarkable that they could scarcely escape attention if they occurred at all freely at Weymouth. Hence though the beds must correspond stratigraphically, we have no encouragement in this country to recognize a "Pterocerian" subdivision. Two other fossils may be noted. *Avicula œdilignensis* occurs in these beds, which may hence be a guide to correlation: and about halfway between the Trigonia-grits and the Gasteropod-bed are bands full of *Terebratula Leymerii*, with associated nodular beds. It would therefore be perfectly defensible to raise the upper limit of the Astartian to this level, except that *E. virgula* has already begun to be abundant. The "Ammonite clays" of Dollfus present no points of interest, as they are but poorly seen and slightly fossiliferous, and they do not attain to the Upper Kimmeridge.

The only other locality examined in Normandy is the neighbourhood of Lisieux and Glos, which presents us with a greater development of a portion of the series seen at Trouville. This locality is included in the general description of Normandy by Caumont, who

* This is not the conclusion I arrived at in my paper on the Kimmeridge clay; and the correction shows the advantage of a personal over a literary acquaintance with the French series.

gives a section of the hill of Glos; and it is specially described by Goubert (29), who, with Zittel, illustrated the fossils found in the sands. Near Lisieux, on the road to Glos, is a quarry very similar to that at Trouville; for at the base is 6 feet of rubbly limestone, then 5 feet of a large-grained oolite, and on the top 20 feet of rubbly coral rag, almost a Thamnastræan reef in places, and containing *Cidaris florigemma* abundantly. This, therefore, represents the true Coral Rag. At a distance of about 3 kilom. from this quarry, on the north side of the bridge leading to Glos, is a very instructive exposure. At the base we have a rubbly coral rag of different character, and obviously either overlying the former, or a changed development of its upper part. The beds are all vacuous by the decay of fossils, only internal and external casts being found. The corals are Calamophyllian, and not Thamnastræan: and there is an abundance of *Nerinæa Goodhallii*, with *Littorina muricata*, *Cerithium muricatum*, *Trochotoma discoidea*, *Chemnitzia delia*?, *Natica corallina*, *Nerita* sp., *Lucina Moreana*, and *L. balmensis*? The whole, by the absence or rarity of *Cidaris florigemma*, by the abundance of *Nerinææ*, and by the character of the corals, reminds one of the Novion limestone, though the lithology is different. Overlying this are oolites and oolitic sands in good beds, 3½ feet; next a breccia of limestone-fragments with a hard 15-inch band of blue limestone in the middle, with *Pleuromya tellina*, a total of 3 feet 9 inches; and then the true sands of Glos. These are marly at the base, but become more sandy by degrees, with hard glauconitic bands or nodules containing fossils; but finally the sand is absolutely unfossiliferous, as it has usually been reported to be at this spot. The thickness here seen is 24 feet; but it certainly extends much further up the hill. The fossils noted are *Ammonites serratus*, *Pterocera polypoda*, *Trigonia Bronnii*, *Gervillia kimmeridiensis*, and *Pecten midas*—a group rather characteristic of higher beds than these are usually considered, and which leads us to look on these sands as partly equivalent to the passage-beds of the coast, especially as Caumont records a section at Pont l'Evêque where the Trigonia-grit lies immediately on the sands of Glos. The quarry just described does not appear to be the place where the usual fossils have been gathered, as they are said to be all small except the *Trigonia*. The common locality in fact is seen on the opposite side of the river, where a greater thickness of sand is seen containing bands white with fossils, the principal of which are *Trigonia Bronnii* and *Lucina circumcisa*. In any case, the exact position at which the sands commence in reference to the coast-section is clear, the lower beds in the quarry representing the first beds above the Coral Rag, and the blue limestone the hard band (called "Calcaire de Blangy") in the Hennecqville Cliff.

IV. The Pays de Bray.

The older works on this district, such as that of Graves (8), have been rendered out of date by the splendid monograph of M. de Lapparent (69), published as one of the memoirs of the Geological Survey of France. Only a small portion of the Upper Jurassic rocks is exposed in this district, brought up to day by a N.W. and S.E. elevation, from the summit of which the Cretaceous rocks have been worn away. It thus affords, as it were, a continuation of the coast-section of Normandy, commencing at the base where the latter ceases, namely in the Virgulian marls. M. de Lapparent classifies the rocks thus exposed as follows :—

Upper Portland.

Ferruginous sandstone, speckled clays, greensand.

Middle Portland.

Blue marls.

Lower Portland.

1. Upper conglomerate.
2. Glauconitic calcareous grit.
3. Marly limestones.
4. Calcareous grit with *Anomiæ*.
5. Beds with *Ostrea catalaunica*.

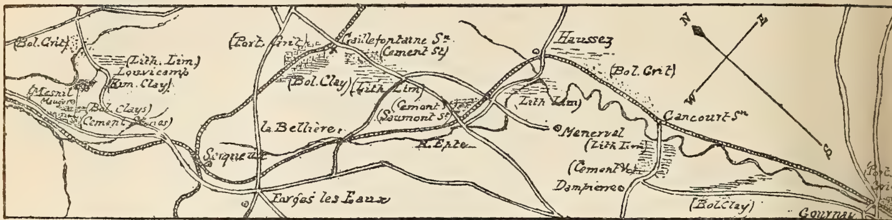
Kimmeridgian.

1. Upper clays and lumachelles.
2. Compact lithographic limestone.
3. Lower clays and lumachelles.
4. Calcareous grit (Pterocerian or Astartian ?).

The accuracy of this description has been verified so far as may be in a brief visit, and the correctness of the correlation determined—with one important exception, which may be the subject of discussion. According to verbal communications from M. de Lapparent, borings executed between the Pays-de-Bray and Boulogne have shown Cretaceous rocks lying directly on Palæozoic ; so that we are not led to expect the Jurassic rocks to be continuous between the two districts. Nevertheless, as we have seen, the lower portions of the deposits under study are remarkably similar to those of England ; and as the true Portland rock of England reaches to Boulogne with little change, we may expect the intermediate beds to be also similar to those of England and differing from them in the direction of Bolonian characters. Judged in this way, the so-called "Lower Portland" (used in the Bolonian sense) of the Pays-de-Bray should begin to show its episodal character somewhat lower in the series.

The lowest bed visible, the sandy calcareous grit, is a very doubtful rock, seen only at one place. One cannot be sure that it is *in situ* ; and its badly preserved *Trigoniæ* and *Astartæ* suggest that it may be a mass belonging to No. 3 of the "Kimmeridgian." In any case it has no particular resemblance to the Trigonia-grit of Havre, and cannot lead to the inference that we are here low down in the Kimmeridgian, as we should be if it belonged to the "Pterocerian or Astartian." The "Lower Clays and lumachelles" with *Exogyra virgula* present nothing worthy of note, except that towards the south they have a thickness of 200 feet, and on the opposite side of the same valley between Louvicamp and Mesnil, which contains the

Fig. 15.—*Map of Part of the Pays de Bray.* (Scale 1 : 240,000.)



grit above discussed, they are not much thinner. The upper portion of this, in which the lumachelles and the intervening material become very sandy, requires more discussion. M. de Lapparent says:—"At the top of this system the lumachelles grow together into solid banks intercalated with very sandy material, and forming rather irregular masses than continuous beds." These sands and doggers are well seen to the north of Louvicamp. The sand is pure; and the doggers are huge; and at the top is a lumachelle of *Trigoniæ*, which appear to be *T. Munieri*. We have therefore the exact representative of the sandy beds at Gris Nez and Mt. Lambert in the Boulogne area. The same is exposed in the railway-cutting south of Haussez, where the beds seen are 10 feet or 12 feet of grits and sands, thickening to the south, and with abundance of *Exogyra virgula*. The presence of this last fossil may at first appear a stumbling-block; and it undoubtedly proves the close connexion of these rocks with the Virgulian; yet, when we compare the Boulogne district, it proves nothing, since the species is equally abundant in the sandy beds which in that area are referred to the "Lower Portland;" on the other hand the petrological similarity is of great weight. Overlying these comes the "Compact Lithographic Limestone," a rock which can be scarcely be matched either in England or at Boulogne. It has a thickness of certainly more than 12 feet, and contains lumachelles of *Trigoniæ* too deeply imbedded for the species to be recorded. At Louvicamp it has also lumachelles of *Exogyra virgula*. The two fossils mentioned by M. de Lapparent are *Ammonites* cf. *gigas*, too characteristic a fossil to be mistaken, and *Gervillia kimmeridiensis*, which might well be *G. linearis*, so similar are the species of this genus. Next comes another mass of clays which are said to be likewise 200 feet thick in the south, but are certainly not so much in the central portion, where examined. There are few fossils in them beyond *Exogyra virgula*, which occurs in lumachelles. It is seen underlying the cement-stone beds of the cutting at the station of Saumont-la-poterie. These cement-stones are regarded by M. de Lapparent as forming the base of the "Lower Portlandian;" and he states that *Exogyra virgula* is entirely and suddenly replaced in them by *Ex. catalaunica*. This is certainly not the case: after the cement-stones begin there are no more lumachelles; but *Ex. virgula* occurs in tolerable abundance in the marls above, at least 6 feet of them. This fossil, therefore, is no more available here for drawing a line at the base of the "Lower

Portland" than it is at Boulogne. The fossils of these cement-stones are abundant; they are *Ammonites suprajurensis, Natica athleta?, Pleuromya sinuosa, Thracia incerta, Cyprina elongata, C. implicata?, Trigonia* (clavellate sp.), *Mytilus autissiodorensis,* and *Anomia lævigata.* The lithological character of these limestones, and the abundance of *Mytilus autissiodorensis* and of *Thracia incerta*, lead one in the first instance to recognize in these beds the cement-stones at the base of the Portland sands; but in face of the abundance of *Ex. virgula* and the presence of *Amm. suprajurensis*, it is safer to look upon these as the more marly portions of the "Lower Portlandian," such as are associated with the conglomerates at Portel and are abundant with the same fossils in Kimmeridge Bay. These cement-stones are cut off from less fossiliferous marly beds above by an intermediate bed of "Calcareous Grits with *Anomiæ*." These two, with the "Glauconitic Calcareous Grit" and "Upper Conglomerate" forming the cap, will then represent the uppermost portion of the Bolonian "Lower Portland" with *Pteroceras oceani.* That fossil is not recorded from the Pays de Bray; but the occurrence of *Trigonia boloniensis, Pecten nudus*, and a *Hemicidaris* called *H. Hofmanni*, but perhaps really *H. purbeckensis*, is highly characteristic. Of the upper beds little is now visible. The blue marls, described by de Lapparent as dark at the base, with *Cardium morinicum* and large *Ammonites* (? *biplex*), and calcareous towards the top, with *Amm. biplex, Pleurotomaria Rozeti, Ostrea expansa, Perna Bouchardi*, and *Cardium Pellati*, are obviously representatives of the "Middle Portland" beds of Boulogne, and are more similar to them than to the corresponding English series. Finally the ferruginous sands seen at Gournay are certainly distinct in appearance from any thing seen elsewhere; and they contain few if any fossils. At their base, however, they contain huge calcareous-grit doggers, which resemble very much those of Swindon and Shotover, the corresponding beds at Boulogne being more regular and calcareous. These contain clavellate *Trigoniæ, Astarte, Corbula*, and *Thracia incerta*? It is above these beds that ferruginous nodules are found, which contain *Trigonia gibbosa* and other true Portlandian *Trigoniæ*, e. g. *T. incurva*, the specimens of which from the Normanville cutting, near Gaillefontaine, preserved in the Ecole des Mines at Paris, are undoubtedly the true forms, though they can no longer be found in a recognizable state. While, therefore, the lower part of the sands and grits may well be the equivalents of our "Portland Sands," the upper part must at least attain the horizon of the Flinty series of Portland.

V. The Boulonnais.

The coast of this district is almost English ground; so well is it known, and so long has it been studied by many of our native geologists. They have, however, published little upon it; and we owe the description of the area first to M. Rigaux (33) and Prof. Hébert (37), and later to MM. de Loriol and Pellat (36, 39, 41, 56, 61), the last-named author having given a final *résumé* of his views in 1878 (68). M. Pellat's classification is now as follows:—

UPPER PORTLAND.

P_4. *Cypris*-beds, 2½ metres.
P_3. Siliceous limestone with *Cardium dissimile*, 2½ m.
P_2. Sands and grits with *Natica elegans* &c., 4 m.
P_1. Sands and calc-grits with *Cardium Pellati*, 3 m.

MIDDLE PORTLAND.

O_2. Clays and glauconitic limestones with *Ostrea expansa*, 13 m.
O_1. Clays with *Cardium morinicum*, 15 m.

LOWER PORTLAND.

Zone of *Cyprina Brongniarti.*

N_4. Sandstones with *Pteroceras oceani* } 10 m.
N_3. Sands with *Natica Marcousana* }
N_2. Conglomerate with *Trigonia Pellati* of Chatillon.

Zone of *Ammonites gigas.*

N_1. Sands and grits with *Amm. portlandicus*, 7 m.
M_2. Shales and upper calc-grits with *Hemicidaris purbeckensis*, 17 m.

UPPER KIMMERIDGIAN.

Zone of *Ammonites erinus.*

M_1. Shale and lower limestones with *Amm. erinus*, 12 m.
L. Sands and grits with *Pygurus*, 4½ m.

MIDDLE KIMMERIDGIAN.

Zone of *Ammonites caletanus.*

K. Clays and upper limestones with *Amm. caletanus*, 18 m.
J. Sands and grits of Conincthun, 2 m.

LOWER KIMMERIDGIAN.

Zone of *Ammonites orthoceras.*

I. Clays and lower limestone with *Amm. orthoceras*, 22 m.
H. 13 beds and little beds of Bréquerèque, 15 m.

SEQUANIAN.

G. Sands and grits of Wirvigne, 5 m.
F_3. White marls and oolites of Bellebrune, 4 m.
F_2. Clays with *Ostrea deltoidea*, 2 m.
F_1. Pisolite with large *Nerinææ* of Hesdin-l'Abbé, 6 m.
E. Red limestone, sands and grits, with *Trigonia Bronnii*, 5 m.
D. Clays with *O. deltoidea* of Brucdale and Mont des Boucards, 10 m.

CORALLIAN.

A'. Coral Rag with *Cidaris florigemma* of Brucdale.
C. Limestones with *Isocardia*. }
B. Limestones with *Terebratulæ*. } Limestones of Mont des Boucards = Pyritous clays and limestones of the South of the Boulonnais, 50 m.
A. Coral Rag with *Cid. florigemma*. }

UPPER OXFORDIAN.

Houllefort limestone with *Pseudomelania heddingtonensis*, 1 m.
Clays with *Ammonites Martelli* and sponges, 1½ m.

MIDDLE OXFORDIAN.

Clays and limestones with *Ostrea dilatata*, 5 m.
Black clays of Wast, 6 m.

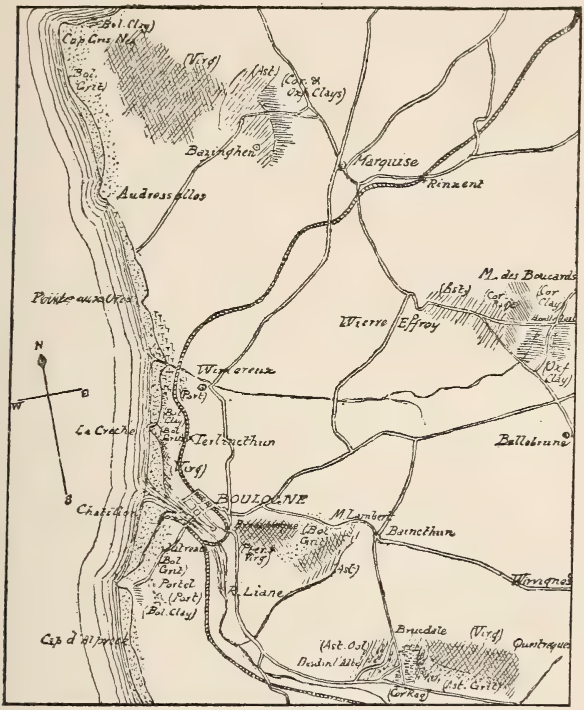
LOWER OXFORDIAN (Callovian).

Fissile limestones with *Ammonites Lamberti*, 2 m.
Clays with *Ammonites Duncani*, 6 m.
Ferruginous clays with *Ammonites calloviensis*, 5 m.

This classification is the result of several modifications of previous ones, especially in the matter of names.

The Upper Jurassic strata in the Boulogne area lie in an anticlinal whose crest has a slope from E.N.E. to W.S.W. Hence the

Fig. 16.—*Map of Part of the Boulonnais.* (Scale 1 : 240,000.)



lowest strata are seen in the E.N.E. corner, and the succession may be traced by passing thence to the sea at Boulogne, whence a divergence to the right or left will show the uppermost portions. The development is also greater towards the S.W., as in the contrary direction we approach the shore-line. From M. Pellat's beds E., or the base of the Nerinæan limestones, downwards, the prevailing character is argillaceous, and the comparatively feeble limestones are merely intercalated masses, themselves usually more or less marly. This feature renders the correlation somewhat difficult, and has given rise to the complicated classifications of MM. Pellat and Rigaux.

The lower groups of clays, estimated by M. Pellat at 26 metres in the north, but at 47 metres in the south-west, have not been specially examined. The uppermost portion, with *Amm. cordatus* and *Millericrinus*, doubtless corresponds to the Nothe grits and clays, and to the beds with *Trigonia spinifera* at Neuvizy, and with *Trigonia perlata* at Trouville. The first mass of importance is the limestone of Houllefort, which is perfectly isolated in the midst of clays, some of which separate it above from the so-called limestones of the Mont des Boucards*. It is extremely fossiliferous; but the discovery of the fossils is dependent on their weathering out, and would be very unlikely in a boring. Twenty-six species are enumerated by de Loriol from this limestone, and additional ones by M. Pellat. Those actually noted were *Trochus houllefortensis*, *Purpura* sp., *Cerithium Struckmanni*, *Chemnitzia* sp. (wrongly called *Pseudomelania heddingtonensis*), *Opis Phillipsii*, *Arca scabrella* (near to *A. quadrisulca*), *Nucula cottaldina*, *Lima rudis*, and *Cidaris florigemma*. There is so much that is peculiar about this fauna that it gives little help in correlation; and the additional *known* species in de Loriol's list, *e. g. Amm. plicatilis*, *Alaria tridactyla*, *Pholadomya Protei* and *P. concinna*, *Trigonia monilifera*, *Lima rigida*, *Pecten vimineus*, and *Ostrea dilatata* are not quite conclusive. Nevertheless, on the whole, the facies is Corallian, and indicates an horizon which may indeed be compared with that of Neuvizy or the Osmington Oolite, but is more like the base of the Corallian in the Haute-Marne and the Yonne departments.

About the succeeding portion of the series there have been several changes of opinion among the French geologists, owing to there being different developments in different parts of the area. The difficulties arising from this are intensified in the Boulonnais by the deposits being exceedingly local and by several minor unconformities occurring in the series, owing to the proximity of the ancient shores. Four localities exhibit different arrangements, of which the sequence may be specially noted. First, in the extreme north near Bazinghen there is nothing but a few feet of clay between the Callovian grit with *Terebratula humeralis* (true) and *Rhynchonella varians* and the Nerinæan or so-called Astartian Oolite; this is a minimum. Secondly, at the Mont des Boucards, there is a maximum; but the whole is essentially argillaceous though dignified by the name of limestone. Only at one spot on the hill-side are seen a large number of loose stones scattered on so restricted a surface as to even suggest the question whether they may not be the débris of ancient buildings. These stones, surrounded on all sides by the clay, are probably a remanié collection, or are due to some special cause which renders their actual position, at a slightly lower level than the fossiliferous beds *in situ*, of little consequence; but their fauna is remarkable for its richness and abundance. The list published and illustrated by de Loriol is very defective, including only twenty-six out of eighty species which M. Pellat has, up to the present, discovered; and half an hour's search obtained the following 30, several of which are not included in de Loriol's list. *Nautilus giganteus*, *Aporrhais elegans*, *A. musca*, *Pleurotomaria hesione*, *Ani-*

* In his later descriptions (*e. g.* 56) M. Pellat places the "Calcaire du Mont des Boucards" immediately above the Houllefort limestone; but in his earlier ones (*e. g.* 41) he recognizes that they are separated by a considerable mass of clay.

socardia elegans, *Trigonia monilifera*, *Arca Sauvagei*, *Cucullœa* (called *quadrisulca*, de Lor.), *Arca rhomboidalis*, de Lor., *Gastrochæna boucardensis*, *Nucula æquilatera*, *Astarte Sauvagei*, *A. nummus*, *A. bruta*, *Lithodomus inclusus* (in *Isastræa*), *Modiola æquiplicata*, *Mytilus pectinatus*, *Lima proboscidea*, *Pecten vimineus*, *P. intertextus*, *Avicula oxyptera*, *Plicatula horrida*, *Exogyra nana*, *Ostrea rastellaris*, *Terebratula tetragona* ?, *Rhynchonella corallina*, *Thecosmilia* sp., *Serpula Royeri*, *Cidaris florigemma*, *C. Smithii*, *Pentacrinus cingulatus* ?. These fossils being collected from the surface-stones, it is quite possible that some may be derived from overlying beds, which would account for their only being recorded by de Loriol as from such. But when we consider also the more important fossils recorded by him in addition to those above, such as *Belemnites nitidus*, *Anatina striata*, *Astarte Michaudiana*, *Opis Phillipsii*, *Arca texta*, *Hinnites fallax*, and *Hemicidaris intermedia*, we see that there is a very feeble minority, almost an absence, of Oxfordian species, and that the whole indicates a higher horizon than the usual *florigemma*-rag. If it be a remanié deposit, it might well be formed by the breaking-up of beds overlying the Coral Rag of Brucdale. The marly beds *in situ* which, with the above exception, continue upwards at the Mont des Boucards the clays overlying the *Opis*-limestone, are well seen in cuttings and quarries on the hill-side. Only here and there they have hard bands; and the term "limestones" is quite deceptive. Only one soft chalky limestone caps the whole, and forms the top of C of M. Pellat. At the base these beds are crowded with *Terebratula insignis* and *Rhynchonella corallina* (quite a repetition of the chalky limestones of Bourges), and here and there are lumachelles of *Ostrea nana*, and occasional deltoid oysters; *Mytilus pectinatus* and *Ostrea solitaria* (*rastellaris*) are also abundant. The other fossils observed are *Ammonites boucardensis* [?], *Nucula Menkei*, *Cardium Dufrenoycum*, and *Astarte nummus*. A total of fifty-one species is recorded from the basal portion by de Loriol, an examination of which shows the same tendency as the above, namely to associate these with true Supra-coralline beds, or at most with the highest part of the Coral Rag, and to make it difficult to conceive how any one could have taken them for Oxfordian. The upper portion, C of M. Pellat, is, above all things, characterized by the presence of *Ceromya excentrica*, *Isocardia striata*, and *Mytilus perplicatus*, fossils which are everywhere more Astartian than Corallian; the others noted are *Arca rhomboidalis*, de Lor., *Cardium intextum*, *C. orthogonale*, *Pleuromya tellina*, and *Exogyra bruntutana*, which have little effect on the correlation. These marls are followed by more dark clays till the ferruginous grits are reached. In the third locality, that of Brucdale and the neighbourhood, are seen at the base 6 or 8 feet of Coral Rag *in situ*, with the *Thamnastrææ* in their place of growth; but the whole thickness is not seen, nor any thing below the Rag. The fauna is an ordinary Rag one, including *Cidaris florigemma* and various Gasteropods and *Limæ*. There is certainly some difference between it and that of the coral stones of the Mont des Boucards. This is doubtless largely due to want of search among the latter; yet what difference there is indicates a higher horizon for them than for the Rag of Brucdale; for the fauna of the Mont des Boucards contains seven species usually found on higher horizons, and that of Brucdale one only, the species of downward tendency being equally divided. The surface of the Rag of Brucdale is eroded; and it was doubtless during the interval thus indicated that the peculiar beds of the Mont des Boucards were deposited, while the overlying marls spread over both areas. The fourth locality is the valley of the Liane near Hesdin-l'Abbé and at Outreau, where two borings were made, by which it is supposed to be proved that the "limestones" of the Mont des Boucards underlie the Rag of Brucdale. Beneath the latter, it seems, there were encountered some "limestones" which were supposed to be identical with (51, 53) those of the Mont des Boucards; but when the proofs are examined, these are found to consist solely in the fact that some shells were brought up which were thought to be the *Ceromya* of the Mont des Boucards—a fact not sufficient, even if the determination were right, to fix the horizon. No other fossils appear to have been obtained, which is rather extraordinary, considering the great abundance of *Terebratula insignis* at the Mont des Boucards. The supposed proof is therefore utterly inadequate, and we may with more probability interpret the boring differently. At the top (see 51, 53) we have, below the alluvium, 22·65 metres of undisputed beds, down to No. 18; No. 18 is 6·40 metres of the Nerinæan oolite of Hesdin-l'Abbé; No. 19 and part of No. 20 (say 3 metres) are the grits with *Trigonia Bronnii*. The remainder of No. 20 are the *Ostrea-deltoidea* marls, 12·90 metres; Nos. 21–23, which MM. Sauvage and Rigaux refer to a coralline limestone, though there are no corals recorded, are attenuated representatives of the Mont-des-Boucards limestones, not well developed and therefore without the *Terebratula insignis*, 4·75 metres. No. 24 is the Coral Rag of Brucdale with *Cidaris florigemma*, 6·60 metres. Nos. 25–29, referred by MM. Sauvage and Rigaux to the Mont-des-Boucards limestones on account of their containing a *Ceromya* at Hesdin-l'Abbé, are the marls above the Houllefort limestone, containing *Cidaris florigemma* and many fragments of fossils; and the poorly characterized beds below are the ordinary Oxford Clay.

The next bed presents no point for discussion; it is a ferruginous grit of little thickness whose characteristic fossils are *Trigonia Bronnii* and *Astarte communis* (*Morini*). Its place, its fossils, and its mineral character assimilate it at once to the sands of Glos, the corresponding beds at Trouville, and the Sandsfoot grits. It is succeeded by the most constant limestone of this part of the Jurassic series. Varying in thickness and somewhat in character, this latter may nevertheless be easily traced from the extreme north near Basinghen to the valley of the Liane. Like the others, it begins in the north by being thin and somewhat sandy, with large-grained oolites only here and there, and few fossils beyond *Terebratula insignis*. It has gained considerable thickness near the Mont des Boucards; at Paincthun the oolite predominates, and at Hesdin-l'Abbé forms thick masses which are extremely fossiliferous, the most noticeable species being *Nerinæa Desvoidyi*, *N. cæcilia*, *Pholadomya hortulana*, *P. Protei*, *Ceromya excentrica*, *Pinna pesolina*, *Pecten midas*, and *Rhynchonella corallina*. From this oolite are also recorded *Cidaris florigemma* and *Hemicidaris intermedia*. All the more important fossils except the *Pholadomyæ* come up from below and finish in this bed. It is, however, coloured on the geological map with those above it as belonging to the "Astartian." It is denoted by F^1 of M. Pellat. The succeeding beds F^2 and F^3, are comparatively unfossiliferous; but their fossils are such as would unite them rather to the overlying than to the underlying beds, *Ostrea deltoidea* and *Trigonia papillata* being the chief recorded. The Grès de Wirvigne, assimilated by M. Pellat to the Trigonia-grits of Havre, is somewhat different from them in mineral character, being more siliceous and full of oysters; it has a thickness of 6 feet, and is overlain by marly beds with hard bands. The fossils observed—*Ammonites Berryeri* ?, *Purpura* sp., *Leda venusta*, *Astarte supracorallina* ?, *Corbula Deshayesea*, *Trigonia Meriani* ?, *Cyprina cyreniformis*, *Pleuromya tellina*, *Pecten solidus* and *P. strictus*, as well as others recorded, such as *Ammonites erinus*, *Lucina substriata*, *L. rugosa*, *Pinna granulata*, *Exogyra virgula*, *Terebratula subsella*, *Pygurus Blumenbachii*, *Rhabdocidaris Orbignyana*—all have a tendency to confirm M. Pellat's conclusion; and scarcely one is more connected with beds below than with those above. It is possible that these grits and associated beds represent more than the Trigonia-grits of Havre and Weymouth, since there is nothing above them that can be called Pterocerian.

The overlying beds, in fact, are seldom seen. On the hill-slopes south of Mont Lambert but little can be made of them; and the same is the case in the north, near Bazinghen. At Boulogne they are hidden beneath the town, and merely a part is exposed at Brequerecque, and contains no fauna which can be specially called Pterocerian. It is perhaps scarcely worth while to separate these beds from the overlying ones, called H and I; but we may usefully characterize this lower mass by the presence of *Ammonites orthoceras*, which is associated with *Thracia depressa*, *Lucina minuscula*, *Pholadomya acuticosta*, *Arca texta*, *Gervillia kimmeridiensis* ?, and *Anomia* sp.; it then represents the zone of that Ammonite, and will be assimilated to Pterocerian beds elsewhere. The succeeding series commences with a very characteristic group of rocks, part of which forms a great bank with white veins on the shore north of Boulogne; and 18 feet of it is quarried along the sides of the great valley between Mont Lambert and the sea. It is everywhere fossiliferous, the most abundant fossils being *Ammonites longispinus*, *Trigonia Rigauxiana*, *Pholadomya acuticosta*, *Gervillia kimmeridiensis*, *Exogyra virgula*, *Terebratula subsella*, and *Serpula tetragona*. This bed forms the base of a series of great thickness, in the centre of which comes the conspicuous mass of soft sand with large cheese-doggers (L of M. Pellat, 33 and 34 of M. Hébert), which is only seen at La Crêche. This makes no show on Mont Lambert, and is probably quite a local deposit. For purposes of comparison it is well to pass over these minor distinctions, and to place all the mass K L M of M. Pellat in one division, or zone, of *Amm. longispinus.* The upper portion is very shaly, and contains, on both sides of Boulogne, *Lingula ovalis*, *Trigonia variegata*, and *Thracia depressa.* The upper limit of this is assumed by M. Pellat to be the remarkable lumachelle of *Exogyra virgula*, which stands out as a broad band in the cliff of Chatillon, but which unfortunately is absent from La Crêche. The base of the "Portland" was originally taken by M. Pellat (39), as by all others, below the great conglomerates; he subsequently included all M as "Portlandian" (62), but finally (68) took only the upper half. Certainly the beds become sandy by degrees, and, for some distance below the conglomerates, begin to indicate coming changes, as may be seen both at La Crêche and Gris Nez. This change, being accompanied by the introduction of a new fauna, including *Ammonites gigas*, *Cardium morinicum*, *Trigonia Munieri* and *T. barrensis*, *Perna Bouchardi*, and *Hemicidaris purbeckensis*, may well justify the lowering of the line of separation, as we so often have to do, the palæontological change being accomplished more quickly than the lithological.

The next portion of the series is perhaps the most interesting of all; and as it is chiefly exposed along the coast, we here reap the benefit of M. Hébert's admirable and accurate researches, which may be referred to for the closest details (37). He describes the three chief localities where these rocks may be seen, viz.:—to the south of Boulogne, from Chatillon to Equihen; to the north, from La Crêche to Wimereux, and at Gris Nez. The shales last noticed are the No. 26 of his sections, and from their thickness form an admirable base. The lowest bed of the "Lower Portlandian" at La Crêche is a 3 to 4-foot band of excessively hard crystalline calc-grit, blue in the interior and without fossils; it is followed by grey fucoidal doggers in sands or clays (not well seen) for 10 feet or more; above come 4 feet of hard yellow sandstone rock, full of a quartzose conglomerate, and a perfect lumachelle of *Exogyra virgula*, covered by a layer crowded with *Trigonia Pellati* and *T. Munieri*, and then passing into 4 feet more of ferruginous conglomeratic grit with the same fossils. These are Nos. 23–25 of M. Hébert. Seeking these on the Portel side, we find the crystalline grit attached here and there to the base of the great conglomerate, but very irregularly; towards the north it sinks by degrees till, opposite the Fort du Mont Couple, it is on the sea-shore. Here it encounters a considerable fault, running nearly parallel to the cliff, and just cutting behind the nearest cliff-quarries of Chatillon*. It is thus thrown to the top of the cliff, and forms the base or perhaps the greater part of the materials worked there, being in both places crystalline and lignitiferous, and overlying the shales more or less unconformably. Above it comes a variable mass of sands and clays, with huge grit

* I at first thought the appearances were due to a local erosion and an *overlap* of the Chatillon beds; but MM. Sauvage and Rigaux suggested a fault, the direction of which was made clear by the observations of Prof. Prestwich during an excursion of the Geological Society of France in September 1880.

doggers, often becoming continuous, which develop to a considerable thickness at Chatillon, are worked there and at Mont Lambert, and constitute the base of Gris Nez. These are capped by the great ripple-marked conglomerate, distinguished everywhere by the abundance of *Exogyra virgula*, *Trigonia Pellati*, and *T. Munieri*, which becomes, however, a mass of false-bedded sand with hard doggers at Gris Nez. These are so associated with the sands below, that the natural subdivision would seem to be made above them, where *Ex. virgula* ceases to be a common fossil; and these two parts, N_1, N_2 of M. Pellat, 23–25 of M. Hébert, may form the zone of *Ammonites gigas*, which certainly occurs throughout.

The next zone is the chief fossiliferous one. It consists, at the base, of soft marly sands with hard bands, N_3 of M. Pellat, characterized by *Perna Bouchardi*; next, of some hard grits in more than one bed (N^4), with *Cyprina Brongniarti*, *Pterocera oceani*?, *Natica Marcousana*, and *Hemicidaris purbeckensis*; and, finally, of earthy beds and sands more or less ferruginous and consolidated, with rolled pebbles and local unconformities. The whole of this does not occupy more than 20 feet at La Crêche. At Portel the middle portion is nodular, and the whole is thicker. At the quarry of Mt. Lambert, nearest Boulogne, the whole appears as massive sandstones; but at Gris Nez the most instructive section occurs. On the east of that point the marly beds are crowded with *Perna Bouchardi* and many other fossils; over these come the hard grits with *Cyprina Brongniarti*, forming a well-marked feature; and above is a local band of green earth, followed by a conglomeratic sandstone and sand, which in the cliff on the south appear to thicken out to nearly 30 feet. The whole in the first locality is overlain by the shales of the "Middle Portland," not previously noticed here. The nodular character of these upper sandstones is noted by M. Hébert in his No. 17′ of La Crêche. With regard to the fossils, *Trigonia Pellati* extends to the top at Gris Nez, and so does *Ammonites gigas* at La Crêche, according to M. Hébert; the others noted are *Nerita transversa*, *Orthostoma Buvignieri*, *Corbula autissiodorensis*, *Corbicella Bayani*, *Mytilus Morrisii*, *Pecten suprajurensis*, *Corbula ferruginea*, from the *Perna*-beds; and from the grits and sands, *Turritella Sæmanni*, *Acteonina Davidsoni*, *Palæomya autissiodorensis*?, and *Ostrea rugosa* in addition.

The succeeding series, constituting the "Middle Portlandian" of M. Pellat, is very well marked. It commences at the base with some 30 feet of black, almost paper, shales, very similar to those of Hen-cliff and of the Upper Kimmeridge of Lincolnshire. These are followed by several cement-stone bands, two being especially conspicuous; and then more shales, with a lumachelle of *Ostrea dubiensis* at the top, making a total of about 50 feet. The fossils are, as usual, flattened in the shales, and in places are innumerable. The most important species noticed were *Alaria cingulata*, *Astarte scalaria*, *Cardium morinicum*, *Lucina minuscula*, *Mytilus autissiodorensis*, *Anomia suprajurensis*, *Discina latissima*, and *Avicula octavia* in the lumachelle. These beds form the O_1 of M. Pellat, and the middle of Nos. 15–17 of M. Hébert. They are seen at the top of the cliff east of Gris Nez with the usual *Astarte.* Above these the beds become softer and more glauconitic by degrees, the lowest being a very fossiliferous band with *Lima boloniensis*, over which is about 48 feet of clays, the upper half of which is more sandy and full of hard bands, and forms a better cliff, the limit upwards being drawn where the sandy clays cease to be glauconitic and to have a blue tint. Lithologically these beds have a very close resemblance to the upper portion of the Kimmeridge Clay of Chapman's Pool, which likewise becomes more glauconitic, and passes gradually into Portland sands, and thence to the Flinty series. The fossils here noted were, in addition to the *Lima* mentioned, *Ammonites pseudogigas, Belemnites Souichii, Pleurotomaria Rozeti, Myacites jurassi, Astarte Sæmanni, Trigonia concentrica?, Mytilus unguiculatus, Pecten lamellosus?, P. Morini, Perna Bouchardi, Avicula octavia, Plicatula Boisdini, Ostrea expansa, O. bruntrutana, Acrosalenia Kœnigi, Cidaris boloniensis*, and *Serpula triserrata.*

The highest beds of the series (P_1, P_2, P_3 of M. Pellat) are only seen in the cliffs on either side of Wimereux to the north, and of Portel to the south. The base consists of about 9 feet of sand and sandstone with fucoidal markings, like the flinty beds of St. Albans; and these contain abundance of large *Cardium Pellati*, and some *Trigonia gibbosa* and other shells closely imbedded. Above is a shell-bed crowded with *Serpula gordialis*, just as happens at Portland and St. Albans. *Natica ceres* and many small *Cerithia* are here abundant. The succeeding rocks are more calcareous repetitions of the same kind, all the hard parts being fair limestones, and the softer quite sandy, making a total of about 15 feet. The limestones are exceedingly fossiliferous, having yielded M. Pellat nearly 70 species; but the whole remains of the same character as the Flinty Series of St. Albans, though in the latter case the sands have been consolidated into flints. The other most noticeable fossils appear to be *Ammonites bononiensis, Natica elegans*, de Lor., *Cerithium Manseli* (near the top), *C. pseudo-excavatum?, C. septemplicatum, Pleurotomaria Rozeti, Trigonia incurva, T. Carrei, Astarte rugosa, Corbicella Pellati* (?=*Sowerbya Dukei* [cast]), *Cardium dissimile, Pecten lamellosus*, and *Echinobrissus Brodiei.* The overlying strata are of very peculiar character, being mostly composed of calcareous rubble and tuff, in which there are scarcely any recognizable fossils; and such as are recorded (*Astarte socialis, Cypris, Cyrena Tombecki*, &c.) are not known in English Portland rocks. The irregular manner in which these lie, with ferruginous beds intercalated in places, according to M. Pellat, forbid us to look upon them as certainly equivalent to the Portland building-stones, which, as a lithological group, or as a palæontological horizon containing *Ammonites giganteus* (true), *Buccinum naticoides, B. angulatum*, and *Cerithium portlandicum*, are not here to be found. There is, in fact, no proof that any thing but Wealden beds overlie the Flinty Series at Boulogne.

Discussion of Results.

From the above observations it is proposed to classify the rocks under consideration as follows:—

1. Portlandian.
   Upper = Purbeck.
   Lower = Portland Limestone.

2. Bolonian.
   Upper = "Middle Portland."
   Lower = "Lower" Portland.

3. Kimmeridgian.
   Virgulian.
   Pteroceriàn.
   Astartian.

4. Corallian.
   Supracoralline.
   Coral Rag.
   Coralline Oolite.

5. Oxfordian.
   Upper = { Oxford Oolite. / Oxford Grit. }
   Lower = Oxford Clay.

The first point to be considered is the upper limit of the Oxfordian group. When the English classification is compared with the French, serious discrepancies are found to exist; for our Lower Calcareous Grit, and part at least of our Coralline Oolite, are in France universally placed in the Oxfordian. In the Ardennes department it has been seen that grits which underlie the Neuvizy ironstone correspond both in character and contents with the Nothe Grits and the Calcareous Grits of Yorkshire up to the Passage-beds; yet these are placed as Middle Oxfordian by Sauvage and Buvignier (2). The richly fossiliferous ironstone forms the type of the Upper Oxfordian for all French geologists; and when we trace its range and that of the rocks which overlie it, this seems justified stratigraphically. For above it lies a series of very changeable limestones, contrasting in this respect with the uniformity of the ironstone; and these same limestones, after the ironstone has died out, are carried on in a recognizable form over other Oxfordian beds. Thus the independence of the two groups is most marked where the dividing line is drawn. The Palæontological separation is also well marked; for out of the 154 species recordedby Buvignier from the ironstone in the Meuse, only 45 pass upwards to any member of the Coral Rag. Excluding the Creué limestone, which forms a kind of passage-rock, the difference is equally marked wherever the fossils have been sufficiently studied, as in the Yonne, where Cotteau shows (16) that, out of 323 species in the lowest Corallian beds, only 17 occur in the Oxfordian, if we draw the line between the two groups as proposed; and even where the lithology is the same, only 17 out of 58 are common. If, then, by stratigraphy, by palæontology, and by common consent, the Neuvizy ironstone and its equivalents are to be placed as the summit of the Oxfordian, the English classification must be modified to bring it into harmony with more widely-established facts. It has been seen, in former studies of our English Corallian rocks, how readily they lend themselves to such a change by the "markedly Oxfordian character of the fauna" of their lower part. It is proposed, therefore, to abolish the term "Lower Calcareous Grit," as associating the rock intended too closely to the "Upper Calcareous Grit," and, as it forms an integral part of the Oxfordian series, to call it the "Oxford Grit," and, for some part at least of the overlying limestones, to revert to the old name of the "Oxford Oolite." These terms, however, are too descriptive to be generally applicable, and, when they are not so, may be replaced by the more general term "Upper Oxfordian."

We may now trace the range of this mass over the area studied. The Ferruginous Oolite of Neuvizy has been placed as the Lower Oxfordian by Oppel (27), partly in reliance on Prof. Hébert's erroneous section (21), which places a mass of clay above it, partly by placing the *Cidaris-florigemma* beds as Upper Oxfordian, but chiefly by including the whole of the underlying clay in the same subdivision, and thus quoting true Oxford-Clay fossils, which are not to be found in Buvignier's lists, such as *Amm. biarmatus* and *Amm. Henrici*. Oppel does not, however, quote *Amm. Lamberti*, which is most characteristic of Oxford Clay. There is not sufficient evidence, therefore, to overcome the weight of that obtained from the list of fossils given above, which places this ironstone as the uppermost part of the Oxfordian, as it is stratigraphically by its immediately underlying the *Cidaris-florigemma* beds. Along the whole of the Eastern range, the Oxford Grit below remains constant, becoming more nodular to the south; and the ironstone reaches nearly as far. The only deposit hereabouts which can give rise to any dispute is the limestone of Creué and Liouville, the highly Oxfordian character of the fossils in which has led Hébert (21) to place it in the Oxfordian; while Buvignier (22) makes it Corallian. Palæontologically, it is undoubtedly more united to the Oolite below; but by its extremely local character, and its alternating with the Rag above, it belongs more to the latter, and must therefore be left as on a kind of neutral ground.

On the change of strike and on crossing the band of Lower Jurassic rocks which extends to the south, we find a change in the development. Grits and ironstones can no longer be found, but the rocks continue to be marly as below; while a new set of Ammonites characterizes the upper part, though the general facies remains the same, the true Oxford Clay, with *Amm. Babeanus* and *Amm. Lamberti* and others belonging to the group *Harpoceras* remaining constant. Below, it would appear that the beds which intervene between these and the Corallian, with their Ammonites continuing from below, as *Amm. marantianus* &c., occupy the place of the Oxford Oolite and Oxford Grit, and are therefore the Upper Oxfordian. Tombeck (50, 55, 57, 64, 65, 66) endeavours to show that the zone of the last-named Ammonite is *above* the Coral Rag; but, his stratigraphy not being accepted, no proof or probability exists of its occupying so anomalous a position. Three are certainly great differences of opinion on the true position of the zone of *Amm. tenuilobatus*, which in the Jura is supposed to represent this—some, as De Loriol, Mösch, Bayan, &c., considering it Astartian, and others, as Hébert, Dieulafait, &c., making it Oxfordian. It would be hazardous to venture an opinion on this point before studying the localities; but the fossils have an Oxfordian facies; and if the zone really corresponds to that of *Amm. marantianus* in the Haute-Marne, it is certainly not Astartian. These are the so-called Marls without fossils, both Upper and Lower, which have never been seen separated by any true Diceras-beds. They form the base at Les Lavières, Vouécourt, and Buxières; and the lower part of the same mass constitutes the marly limestones of Maranville, and the upper the cement-stones of Clairvaux, in the Aube. Further west, in the valley of Laignes, the gritty character comes in again, with similar fossils to those in the Meuse. In the Yonne we find the true Oxfordian marls with their *Harpocerata* at Ancy-le-Franc, and above these the Upper Oxfordian, in the new form of massive calcareous sandstone, at Pacy, in the valley of the Armançon. The ironstone of Etivey has unfortunately not been examined; but by its fossils it might well represent the Oolite of Neuvizy, except for *Ammonites lunula*. In the neighbouring valley of the Yonne the Upper Oxfordian is recognized in the siliceous limestones underlying the great white limestones of Coulanges, referred to the Corallian. Great differences of opinion have been expressed about the correlation of this portion. In their general work Leymerie and Raulin (25) placed the Etivey ironstone as Lower Oxfordian, as also the beds at Ancy-le-Franc, which they nevertheless considered lower still. The Pacy freestones they called Middle Oxfordian, and paralleled with the Coral Rag of Châtel Censoir, leaving the lithographic limestones only to represent the Upper Oxfordian. This, however, has been proved to be wrong by Cotteau (16, 34), who showed the essentially Corallian character of the limestones of Coulanges and of Vermanton, and discovered the Coral Rag at the base of the lithographic limestones. The fossils and the stratigraphy are all in favour of the latter author's view. M. Hébert (21, 31) recognizes in the Etivey ironstone an equivalent of the Neuvizy, and says it plunges beneath the limestones of Ancy-le-Franc. The latter thus becomes his Upper Oxfordian; and in the same horizon with it he places the freestones of Pacy, which are the equivalent of the upper part only, and the limestones of Vermanton, which have been proved Corallian. He considers it also the equivalent of the Creué limestone, which is above the Ferruginous Oolite. Some of these correlations may be rejected; but there is unanimity on the Pacy freestones representing the Upper Oxfordian, in spite of the recorded presence of *A. Babeanus*. In the valley of the Loire the Upper Oxfordian is lost in the unfossiliferous marls; and in that of the Cher it must lie in the lithographic limestone mass, since the fossiliferous sponge-bed is characterized by *Ammonites canaliculatus* and other species belonging to a lower horizon, though the recorded presence (60) of *A. marantianus* shows that we are there not far off the top. In the Lower Charente, the locality Marans has beds below any thing seen at La Rochelle. In the Sarthe the description of M. Hébert (21) would lead us to place his "Middle Oxfordian" as Oxford Grit, which here returns to its usual character, and his "Upper Oxfordian," which is here marly, as Oxford Oolite. On the coast of Calvados we find in the Trouville Oolites, seen in true succession in the cliff of Auberville, a good palæontological representative of the Neuvizy ironstone; and below comes the Oxford Grit, with an equally characteristic fauna. The lower of these two beds is considered by Hébert (28) to be Middle Oxfordian, and therefore to correspond to the Neuvizy ironstone, and the rest to be Upper Oxfordian; but the Neuvizy ironstone is certainly more allied palæontologically to the upper beds, and the grits associate themselves with these more completely than with the beds below.

The series here, as has been seen, corresponds exactly with that at Weymouth—the Nothe Grits, the Nothe Clays, the Bencliff Grits, and the Osmington Oolites all following regularly. The last named, therefore, are to be specially paralleled with the Neuvizy ironstone, with which they have 29 per cent. of their fossils in common, and must be called Oxford Oolite, and the grits below, Oxford Grit. Whether the Trigonia-beds of Weymouth are to be also included is a more difficult matter, to be discussed hereafter; but we must certainly place on the same horizon the pisolites of North Dorset and the oolite of Highworth, which has 57 per cent. of its fossils common to Neuvizy, and perhaps also the road-stones of Faringdon. Unfortunately at Oxford the "Oxford" Oolite is not well represented, except near Marcham. At Upware the limestones of the north pit belong here. The great development in Yorkshire gives us for the Oxford Grit the whole mass up to and including the Passage-beds, and for the Oxford Oolite as far up as the Trigonia-beds of Pickering, the latter having 55 per cent. in common with Neuvizy. In fact, the greater part of the limestones which underlie the Coral Rag proper belong to this portion.

Our circle is finally completed in the Boulonnais, where the limestone of Houllefort, in the midst of clays, offers us the only representative of this part of the series, though to what exact part it may be considered to correspond may be doubtful. The exceptional presence in it, however, of *Cidaris florigemma* indicates a high position.

We have next to discuss the Corallian series. De Loriol (50, 56) and Tombeck would have us abolish the term altogether; and Oppel (27) practically does so by including his "zone of *Cidaris florigemma*" in the Oxfordian. The argument against its use is that coral-growth is only an accident which may happen at any time, and that there is much of the so-called Corallian which has no corals in it. These statements are doubtless true, and yet, to one who has traced the series from end to end of the Paris basin, they seem to have no weight. The Corallian series, as now to be limited, is one of the best-marked groups it is possible to conceive; but, as Buvignier (22) has so well expressed it, its constant feature is inconstancy. Below this group we may have some continuous beds; above it the beds are markedly continuous; but within it discontinuity is the rule. It is quite to miss the mark, therefore, to say, as Tombeck says (50 &c.), that its normal form is the compact limestone, and coral-growths and Diceras-beds abnormal. No one kind of deposit is more normal than another, except in this way, that the variety which is most frequently repeated, and which occurs at several horizons and under the most varied forms, is a coral-growth, and neither above nor below the limits of this series can *such* coral-growths be found in the country examined. Hence, unless one were to invent a new term, such as *Protean*, to indicate variability, no better name could be chosen than Corallian to indicate this most name-needing group.

In the study of the English Corallian we have stated* that the Coral Rag, with *Cidaris florigemma*, is always at the top of the limestones, while the French geologists have asserted it to be as constantly at the bottom. This anomaly is now explained. By marking off so much of the so-called Coralline Oolite to place it in the Oxfordian, we leave the Coral Rag nearly, and in most places quite, at the base. Sometimes, as near Oxford, it lies on the Oxford Grit; sometimes, as at Upware, on the Oxford Oolite; and only here and there can we suppose, and that doubtfully, that any oolite belonging to this series rather than to the Oxfordian, and hence to be called Coralline Oolite, intervenes. It may be so at Malton and Seamer, in Yorkshire, especially where shell-beds are developed; and it may be so at Weymouth, where we may possibly call the Trigonia-beds by this name. As for *Cidaris florigemma*, it is characteristic of the Corallian as a whole, and is perhaps not confined to it. Tombeck describes (55) a bed abounding with it at St. Ansiau, in the Haute-Marne, supposed to lie in the Oxford Clay, though a fault is here possible; and the Houllefort limestone, which cannot be called Corallian, contains it; on the other hand, it is found in Astartian beds at Weymouth. But, after experience of its habit, it is impossible to say more than that it is commoner towards the base than towards the top of the Corallian series, and is usually associated with massive corals. As to there being a bed full of it constantly marking the junction with the Oxfordian, as Hébert says (21), this is a feature that seldom occurs.

The upper line separating the Corallian from the Kimmeridgian is rather hard to draw. Tombeck says (50) that, if we take the so-called Astartian as the base of the latter series, it cannot be drawn palæontologically; and de Loriol (50, 56), on the strength of this, wishes to call the Astartian and Corallian by one name, Sequanian. On the other hand, Hébert (19, 31) says that one can put one's finger on the line of junction, and

* Blake & Hudleston, Quart. Journ. Geol. Soc. vol. xxx. p. 313 &c.

that the two series are perfectly separate by their fossils. The latter supposition we may dismiss, as it is exceedingly improbable; and it has been shown (p. 529) that in the Aube several such apparent junction-lines occur, one above the other. On the other hand, Tombeck's statements appear to be vitiated by his including the Oolite of La Mothe in the Astartian, instead of associating it with the Diceras-beds; and if this rectification were made, we should find one palæontological distinction indicated by himself—namely, that while the Corallian contains the zone of *Cardium corallinum*, the Astartian contains that of *Terebratula humeralis*. Admitting, however, that the actual line may be rather arbitrary, and that some Corallian forms occur above it, and even Oxfordian ones, if *Ammonites marantianus* be truly recorded, yet if it be drawn not far above the Diceras-beds and ther equivalents a change is soon perceived after the line is passed, as will be shown in the sequel We shall then have three subdivisions in the Corallian series, which may or may not be developed in any particular locality, and the distinctness of which may often be lost, but which are nevertheless sufficiently constant to make it important to recognize them. The upper division, or "Supracoralline," almost wants a better name than it has received. Its most remarkable form, the Diceras-beds, would almost induce us to apply that name, but that the form is too local. The term "Supracoralline" is applicable in the great majority of cases; but the beds must not be supposed to be always above the actual coral-growths. The middle division, or "Coral Rag," is so called to denote the more common position of the Astræan corals, generally associated with *Cidaris florigemma*, though this portion may be without such corals, which may occur above it instead. And the lower division, or "Coralline Oolite," represents those limestones which lie in certain places above the best representative of the Upper Oxfordian in the district, and yet below the beds identified as Coral Rag: it is a division which in most districts may be ignored.

We must now trace these beds in their range. In the Ardennes we find, immediately above the Ferruginous Oolite, a comparatively thin bed of crystalline coralliferous limestone, with *Cidaris florigemma*, which may be recognized at once as the Coral Rag. It is surmounted by the magnificent limestone of Novion, in which *Cidaris florigemma* is rare, if present, but which contains *Cardium corallinum* and some *Dicerata*. These, though full of corals, are the Supracoralline beds, becoming oolitic above, and affording no well-marked upper limit. On entering the Meuse we immediately find the Coral Rag to have increased, and to have developed various forms, such as oolites and crinoidal limestones. There is, however, no regularity in these minor beds, since near Verdun the crinoidal limestones are beneath coral-growth, whereas near St. Mihiel they cap it. Near Verdun some shell-beds are found which might be called Coralline Oolite. The Supracoralline beds are much thicker. In fact, if we are to keep the Astartian beds at all comparable to each other, and to include all rocks of the Diceras-bed type in the Corallian, we must absorb into the latter a considerable portion of Buvignier's Astartian. At

St. Mihiel we have a thin bed below the coral-growth, which is best called Coralline Oolite ; and it is probably the end of the great limestones of Creué, which also will be placed as such. Buvignier has himself (22) recognized that the Coral Rag of St. Mihiel is no other than that of Verdun, and it is only one facies of the beds of this age. The Supracoralline division retains its former character, but begins to have true Diceras-beds on the top, especially in the south (21). In the extreme south the Coral Rag develops into a very thick mass, which is very rubbly and fossiliferous towards the base, with *Cidaris florigemma* &c., surmounted by white chalky limestone, and finally by compact limestone beneath the Astartian beds ; so that here the distinctions of the two parts of the Corallian are less marked. In the Haute-Marne, at Reynel, in the east, the rubbly Coral Rag occupies the base, and more compact limestone lies above it (55), with a development of the Diceras-beds above. In the valley of the Rognon there is a band of disaggregated Oolite at the base (19), then a fine development of the Rag, and a magnificent display of the Supracoralline beds in the form of pisolites with *Diceras*, with compact and oolitic beds associated, up to the more marly Astartian beds. In the valley of the Marne the Supracoralline Diceras-beds have become the summit ; and beneath come the massive coral-growths with *Cidaris florigemma*, occupying a great thickness, and having below them massive limestones, which might be called Coralline Oolite ; but as, according to Royer (12), they have rubbly rag below them at Soncourt, they must be placed as a development of the Coral Rag. Passing west towards the Aube, the Diceras-beds become more restricted, and confined to the upper part, as at La Mothe, while the coral-growth or rubbly beds beneath lose their character, or remain as shelly limestones only. On reaching the valley of the Aube itself, all is united in an undistinguishable mass of limestone, with only a shelly representative of the Supracoralline beds ; and Astartian and Corallian form one massive, lying on Oxfordian marls at Clairvaux, and covered by Pterocerian marls near Bar-sur-Aube. Travelling west to the valley of the Laignes, new developments arise. The thin shelly band is replaced once more by Diceras-beds of considerable thickness, and the beds below put on a characteristic form at the base; for below a mass of compact and false-bedded limestone comes a rubbly mass of coral-growth, full of the shells which usually accompany it, though *Cidaris florigemma* was not noticed. This again might be called Coralline Oolite, but that it is believed to develop into Coral Rag later on. In the valley of the Armançon this lower shelly mass has again dwindled down to a narrow band ; so that it was left to Cotteau, or rather to M. Lettéron (43), to discover it, filled with corals and the usual shells and echinoderms, underlying the lithographic limestones. This discovery seems to give the *coup de grâce* to the idea of the latter being Upper Oxfordian (25). They are, in fact, the continuation of the compact limestones of the Laignes valley ; and in various beds contain a Corallian fauna, the uppermost of which, met with by M. Hébert near Angy, seems to have led him (31) to place the limit of the Oxfordian too high, *i. e.* above instead of below the lithographic limestones, which are very different from the limestones of Pacy. In fact, the limestones of Angy and Tonnerre are shown to be the Supracoralline beds, and do themselves contain Diceras-beds, especially at the top, though the whole is enormously developed, so as easily to mislead one. On passing westwards, however, to the valley of the Yonne, still more is in store; for while in the neighbourhood of Bailly and Vincelles the Supracoralline beds occur in all their characters, beneath them are still found the lithographic limestones, more than usually marly at Vermanton; and below these again the coral-beds of the Laignes valley, so much reduced in the Armançon, burst out into a magnificent mass, wherein corals of all kinds, *Diceras*, *Nerinœa*, and all the Rag fauna are confusedly mixed in extreme abundance, as may be seen so well at Merry-sur-Yonne, Châtel-Ceusoir, and, in a more uniform character, in the white limestones of Coulanges. It is this development that for ever negatives the idea that Diceras-beds are necessarily above the Coral Rag, though these *Dicerata* differ from those of *the* Diceras-beds in apparently having lived near the spot, and in not having been rolled. Beyond this valley the Corallian once more changes, and by degrees returns to the dead uniformity of a lithographic limestone. In the valley of the Loire the lower Diceras-bed is seen in diminished thickness near La Charité, succeeded in an upward direction by compact limestones, which show no more character than that of becoming oolitic near Pouilly. On the left bank of the river, however, it is stated (32, 60) that the Lower or Coral-Rag Diceras-beds are not to be found, but that the Supracoralline ones are once more developed at Sancerre. These last take up again their Armançon form near Bourges, and show, not quite at the summit, the white limestones of Angy and Tonnerre. Hence to the Cher is the path of degradation; for in the latter valley even less can be distinguished than in that of the Aube, but all is lithographic. In the Charente department the Corallian rocks remain still massive and but slightly characterized, though coral-beds are developed in what may be considered the equivalent of the Coral Rag. The Supracoralline beds are still characterized by the abundance of *Nerinœœ* and by the presence of *Diceras* and *Cardium corallinum*. In the Lower Charente, on the shores of the Pertuis d'Antioch, the Corallian rocks put on a fresh form, the lower part being a white fossiliferous limestone, which, by its fossils, may represent the Rag; while the true coral-bearing beds are on a horizon usually "supracoralline," and are parallel with the similar development in the Ardennes. It would appear that d'Orbigny included still higher beds in his 'Étage Corallien' here; but a comparison of the series in the two Charentes and the general fauna indicate the necessity of drawing the line separating the Corallian from the Astartian almost immediately above the coral-reef of the Point du Ché. In the departments of the Orne and Sarthe, according to Hébert's description, there would appear to be no development of corals on the usual horizon; but the Supracoralline beds contain *Diceras* and are overlain by coral-growth, which is thus on a higher horizon than almost anywhere else.

On the coast of Calvados the sequence is tolerably plain; for the beds characterized by *Cidaris florigemma* succeed immediately to the Trouville Oolite, and thus occupy the base. They change laterally into coral-growth, which represents the Coral Rag; so that there is little, if any thing, that can be called "Coralline Oolite," unless it be the mass that underlies the Rag in the Trouville quarry. The Supracoralline beds are here quite different in form from those in the southern range, being arenaceous, instead of calcareous or coralliferous; nevertheless they contain calcareous matter, and are admirably marked off stratigraphically from the beds above by the difference of lithological character. The arenaceous character of these beds appears to prevent their assimilation palæontologically with their calcareous representatives, the two sets having little in common; nevertheless the fossils afford no negative to their stratigraphical correlation. In the well-known neighbourhood of Glos, in like manner, can be traced the Coral Rag in all its commonest characters, with perhaps a representative of a Coralline Oolite below. Above, we appear to have a twofold development of Supracoralline beds:—one, at the base, being calcareous and similar to the Novion limestone and other southern supracoralline beds, wanting only the *Diceras*, but with abundance of ramose corals; the other, above, being an enormous development of loose sand, corresponding to similar beds on the coast, and containing a fauna which indicates a high position. These sands were placed by Zittel and Gouert (under the guidance of Hébert) as Upper Corallian, which corresponds to the above-assigned place. Their relation to the coast-beds, and the correspondence of the latter to the Sandsfoot-Castle beds of Weymouth, leave no doubt that the latter must, with them, be placed as Supracoralline. We come thus to the discussion of the Corallian of Dorset. There seems little doubt that, the Sandsfoot-Castle beds being Supracoralline, and the Osmington Oolite Upper Oxfordian, we must find the beds corresponding to the Coral Rag between these limits. What actually does intervene is the Sandsfoot Clay and the Trigonia-beds. The abundant fossils of the latter still leave some doubt as to its proper position. On the one hand, such fossils as *Gervillia aviculoides*, *Ammonites cordatus*, *Pecten fibrosus*, and *Echinobrissus scutatus* are extremely Oxfordian; while the presence of *Ostrea deltoidea*, *Cidaris florigemma*, and *Thamnastræa arachnoides* attaches the rock to the Corallian. The knot can only be cut by calling it a passage-bed, or by placing it with other similar puzzles as "Coralline Oolite." It cannot, however, properly represent the true Coral Rag; and thus we are driven to look upon the Sandsfoot Clay as being its equivalent here, a correlation not without value when other northern localities are considered. In North Dorset the lower limit of the Corallian, as now defined, is very well marked; for the uppermost Oxfordian is the false-bedded series, and the overlying rubbly beds with *Cidaris florigemma* cut off the upper edges. Nevertheless the palæontology is not altogether satisfactory; and we are obliged to allow a wider range than usual for more than one characteristic fossil, *e. g.* *Echinobrissus* *scutatus* and *Hemicidaris intermedia*. At Westbury the Corallian would appear to be almost absent; for we must now refer the rubbly beds with *Echinobrissus scutatus* to the Upper Oxfordian, and the iron-ore itself is nearly, if not quite, Astartian. The ferruginous character of rocks appears in some way connected with such gaps. In the neighbourhood of Westbrook, Wiltshire, a coral-bed has been described* from which *Cidaris florigemma* is absent, and which, on that account, is considered older than the usual Rag. This may be so; but, in view of the similar Rag in the Aube department passing into a true *florigemma*-Rag in the Yonne, the difference cannot be of much importance, either here or elsewhere. It certainly need not be considered an Oxfordian reef. At the Calne quarries the lower clays, like those of Hillmarton, abound in *Cidaris florigemma*, and the bed with *Hemicidaris intermedia* occurs towards the base; hence an examination of these quarries alone might lead a foreign geologist to call the freestones Supracoralline; but the error of such a correlation is easily proved by the *overlying* coral-growths observed in the heights on the north and south immediately beneath the Kimmeridge Clay. There is little, in fact, in this district to represent any Supracoralline beds. The same is true all the way to Oxford, the ferruginous earth being the only deposit referable to them. The only Corallian rock is the Coral Rag itself, unless we call the great quarries at Wheatley Supracoralline, for which their great resemblance to the limestones of the Ardennes and the Meuse might be an argument. The arrangement of the Yorkshire beds is not very easy, because it is rather difficult to decide which of the beds underlying the Rag should be placed with the Oxford oolite, and which should be associated more closely with the overlying mass. Referring to our comparative sections (Q. J. G. S. vol. xxxiii. pl. 12), the abundance of *Echinobrissus scutatus* in the Lower Oolites of Grimston mark them as Oxfordian; while the "mamillated-urchin series," by its *Cidaris florigemma*, is as plainly Corallian. The Chemnitzia-limestone of Malton is just one of those doubtful deposits to which it is best to apply the name Coralline Oolite. At Pickering the rubbly nature of the base of the Upper Limestones, *g*, and the introduction there of corals, added to the change of fauna, indicate that the base-line of the Corallian should be drawn almost directly above the Trigonia-beds. It will then be seen that the shell-beds at the top of the Lower Limestones are more connected with the uppermost Oxfordian than with the Corallian. As to the Supracoralline beds, they are simply equivalent to the "Upper Calcareous grit," which latter is parallel to the Sandsfoot grit, and not altogether above it as we previously supposed (*l. c.* p. 390), owing to the non-recognition of the Sandsfoot clay as the equivalent of the Coral Rag.

In the Boulonnais the clays with marly limestones of the Mont des Boucards were first called Oxfordian by Rigaux (33), apparently because they seem continuous with the marls below; but on the discovery of the coral-bearing beds at the base or lower part

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 288.

(41), Pellat was compelled to place them at least as Corallian, as he identified the Coral Rag with that of Brucdale, and, at the same time, noted that the overlying marls are on the horizon of the compact limestone of Vouécourt and of Tonnerre, both of which are Supracoralline. At a later date (56), owing to the supposed proof by Sauvage (51) and Rigaux (53), that the equivalents of the marls of the Mont des Boucards underlay, in the soundings, the Brucdale Coral Rag, he met them halfway, and placed the two as equivalent. With the breakdown of that proof is lost the necessity of disturbing the former more correct reading, by which the coral-bearing beds of Brucdale and the Mont des Boucards are the true Coral Rag, and the marls of the latter place are Supracoralline, though not developed at Brucdale. The occurrence, however, of *Trigonia Bronnii* in a ferruginous bed above is too close a resemblance to the development at Glos and Sandsfoot to allow us to place them in the Astartian: and we must raise the limit of the Supracoralline to, at least, the top of this bed.

The next division is the Kimmeridgian. Its limitation above will be discussed later on; as to its lower limit, a point much disputed is, whether the beds called Astartian are to be included with it, or with the lower beds. It is to this portion of the series, it appears, that the term Sequanian was first applied by Marcou*; and it was considered part of the Kimmeridgian, while Thirria † had previously called it Astartian. Neither of the original localities for these names has, as yet, been examined; but the latter is adopted as most generally in use for a distinct portion of the series. De Loriol (61) is probably the chief advocate for uniting the Astartian with the Corallian under the term Sequanian, led thereto, perhaps, by the supposed sequence in the Haute-Marne, and by his objection to the term Corallian. It is, however, noteworthy that almost every stratigraphist separates the Astartian from the Corallian, to associate it with the Virgulian or Pterocerian in one great group. It is so in the description of the Ardennes (2), of the Meuse (13), and in Royer's original description of the Haute-Marne (4). It is *not* so in Leymerie's description of the Aube (7), probably because he held all the limestones at Clairvaux to be Astartian, nor in the same author's description of the Yonne (25). But it is practically so in Cotteau's description of the same (42), as the white limestone is made the uppermost bed of his "Sequanian," which thus really is Supracoralline, and the true Astartian beds are left for the Kimmeridgian. It is so in the Nièvre (32), in the Cher (60), and in the Charente (24); while in the Lower Charente, the coral-limestone being the highest Corallian bed, it may be taken that the Astartian is not specially recognized. On the coast of Normandy no one thinks of associating the Trigonia-beds with the Coral Rag, or Supracoralline, though they succeed the latter immediately; and a study of the rocks in the Boulogne area leads Pellat to the same conclusion (41).

* Recherches géologiques sur le Jura salinois, p. 116: 1846.

† "Notice sur le terrain Jurassique," Mém. Soc. S. N. Strasbourg, 1830, p. 26.

There may be some difficulty in drawing a line; but throughout the whole of the eastern and southern range one finds a marly character of deposit setting in again over the true Supracoralline beds, often showing much rubble and indications of local unconformity, as we should expect on the introduction of a new series. The same is more remarkably true in the North and in England; only in the Boulonnais is there somewhat more difficulty in drawing the line. The fossils are usually sufficiently distinct, *Terebratula Leymerii* being a characteristic form. The conclusion, therefore, so tenaciously held by Hébert (21), seems to be the true one, that these beds are a part of the Kimmeridgian. The thickness of the beds assigned to the Astartian by the describers of the different areas is very varying. Thus, in the Ardennes they are said to be 21 feet, but in the Meuse 400 feet; on the Haute-Marne, again, they are supposed to be thin. It is plain, therefore, that a large portion of the 400 feet (if truly determined) must really belong to the Supracoralline, as supposed for other reasons. Their assigned thickness in the Aube is due to a mistake, as before noted; in the Yonne again they are called 33 feet; in the Cher, down to the base of the Nerinæan Oolite is 35 feet, though 80 feet more are included by Douvillé. The whole is therefore of comparatively small thickness, and forms only a subordinate portion. The Kimmeridgian is thus divisible into three—Astartian, Pterocerian, and Virgulian. The first of these is practically defined above. The Pterocerian is adopted solely in deference to its probable justification in the area where it was first introduced, namely the Jura, and to its distinctness palæontologically when the fossils of any locality have been carefully studied. Neither in the basin of Paris, nor in any other part yet studied, is it sufficiently distinct to be of much importance in the field. The Virgulian is the most easily recognized Kimmeridgian deposit, because the characteristic oyster occurs constantly in lumachelles; but it is not confined to this part of the series, either in an upward or downward direction.

In the Meuse department, and probably in the Ardennes, the Kimmeridgian is highly calcareous, the Virgulian portion alone being marly. In the former there still remains some doubt as to the true limits of the beds, and even as to their stratigraphy. While the lower portion of the Astartian requires to be added to the Corallian, the upper group appears to represent the Pterocerian as well, from the abundance, as recorded, of *Pteroceras oceani*, &c. The lower portion abounds in the characteristic *Ostrea deltoidea*. As Tombeck points out (40), the Virgulian must be made to include the marly beds at the base of Buvignier's "Calcaire du Barrois," since these contain *Pholadomya acuticosta* as well as abundance of *Exogyra virgula*. In the south of the Meuse department, if we place the compact limestones in the Corallian, we find the Astartian well characterized as rubbly limestones; and a comparison of this locality with the Haute-Marne in the valley of the Rognon, would lead us to commence the Astartian *above* the lithographic limestones which overlie the Saucourt oolite. Nevertheless it is to be noted that both Buvignier in the Meuse, and Royer originally in the Haute-Marne, included the lithographic limestones in the Astartian, and Tombeck and Pellat do the same. It is therefore possible that the line of junction ought to be carried further down. In the south of the Meuse the Virgulian beds are well developed and very fossiliferous; but the lower portion has not yet been satisfactorily marked off as Pterocerian, although from the recorded occurrence of *Pteroceras oceani* at Mauvage, and the distinct grouping of the fossils on the several horizons, such a subdivision might doubtless be made. Tombeck has divided his Kimmeridgian into two zones, those of *Amm. orthocera* and of *Amm. caletanus*, corresponding to the Pterocerian and Virgulian respectively; and these subdivisions are accepted by Pellat. In the Aube, contrary to the description of Leymerie, the Astartian commences above the chalky limestone, and is characterized throughout by rubbly and oolitic beds, with abundance of *Terebratula Leymerii*. Near Bar-sur-Aube something of a Pterocerian group may be made out; but the fossils have not been sufficiently studied to draw a satisfactory line, which must be a palæontological one. In the valley of the Armançon we have the same difficulty as in the Yonne to decide how far above the Diceras-beds the Astartian must commence, the rubbly beds next above containing rolled corals as well as *Terebratula Leymerii*; but perhaps the line is best drawn above the solid oolite block, as is done by Hébert (21) in the neighbouring valley of the Yonne. No subdivisions corresponding to the Pterocerian and Virgulian have been made out in these western districts. *Pholadomya acuticosta* is the most characteristic fossil. As to the neighbourhood of Bourges, the chief feature is the strong development of a Nerinæan oolite. The beds below this still containing a species of *Diceras*, seem certainly more referable to the Supracoralline, in spite of their lying so far above the white limestones certainly recognized as the latter; and it might be a question whether the Nerinæan oolite ought not also to be placed below the line of separation; but the presence of *Pholadomya Protei*, *Terebratula Leymerii*, and *Trigonia Baylii* may be allowed to decide it in favour of the consensus of opinion. In the Charente, the three portions of the Kimmeridgian are recognizable, the Astartian commencing where the beds become more marly and contain *Ceromya excentrica* abundantly. This latter, however, is not a fossil which can exclude beds from being Supracoralline; and we may still regard the line, therefore, as rather arbitrary. The upper two zones are well distinguished palæontologically. The same may be said of the Lower Charente: the Astartian may be commenced with the marly beds of the Point d'Angoulins, with abundance of *Terebratula Leymerii*, also *Pholadomya Protei* and *Ceromya excentrica*, the latter certainly becoming locally characteristic; and the Pterocerian and Virgulian are well distinguished, according to Hébert (54), at the Point de Châtellailon. In Normandy, as at Weymouth, the Astartian beds are better characterized than elsewhere. The change from the calcareous grits of the Supracoralline is very marked; and the beds included in the zone, viz. the Villerville beds and the Trigonia-grits of Havre, with any *Ostrea-deltoidea* beds above them, have well-marked features of their own.

There cannot be any doubt of the correspondence of these beds to those called Astartian throughout the whole of the southern range; and from this it follows that the Kimmeridge passage-beds of Weymouth are the exact representatives of the same portion. It seems also most satisfactory to place the Abbotsbury and Westbury ironstones in the same horizon, as they are apparently higher than Supracoralline. The lowest beds of the Kimmeridge Clay seen in the Wootton-Bassett cutting, with *Rhynchonella inconstans*, and the great *Ostrea-deltoidea* beds of Lincolnshire, belong here also.

On the south bank of the Seine, it is probable that at Honfleur Pterocerian beds may be developed, though not well seen; but the great mass of the clay at the Cap du Hêve belongs to this division—that is, the " Marnes à Ptérocères " of Dollfus, and the beds nos. 7 to 14 of Lennier. In spite of the abundance of *Exogyra virgula*, and even of *Terebratula Leymerii* in certain beds, this portion is well marked palæontologically by its numerous *Pterocerata*. The Ammonite-marls above, so far as seen, belong to the Virgulian.

Doubtless the same subdivision might, with care, be made at Weymouth; but as yet, in spite of the many collectors who formerly searched the shore, no Pterocerian fauna has been brought to light. The Kimmeridge Clay of England has been shown to be divisible into two groups*, formerly called Upper and Lower Kimmeridge. The term Kimmeridgian must now be confined to the latter; and though the subdivision into Pterocerian and Virgulian is not very clear, it may, perhaps, fairly be taken that the absence of *Exogyra virgula* (as in Lincolnshire), indicates the former, while its abundance (as at Ely, Swindon, and in parts of the southern coast section) indicates the latter. The idea expressed in the paper quoted, that the Lower Kimmeridge Clay represented the Astartian, was founded on the abundance of an *Astarte* which at least is very like *A. supracorallina*. It may, however, be distinct; and in any case its presence cannot be allowed to interfere with stratigraphical conclusions supported by the general palæontological facies.

In the Boulogne area we have the same difficulty in drawing the lower limit as at Bourges. While, on the one hand, there need be no hesitation in including the Grès de Wirvigne in the Astartian, or the Mont-des-Boucards marls in the Supracoralline, the three intervening deposits are doubtfully attached either to one or the other. It is certain that, in the Meuse, Buvignier would include such beds as the *Ostrea-deltoidea* clays in the Astartian; yet the ferruginous bed above with *Trigonia Bronnii* seems to unite both, through the Normandy sections, to the Supracoralline, as has been seen above, p. 563. The important *Nerinæa*-oolite, again, is connected with the lower series by the abundance of that genus, nowhere characteristic of Astartian, but constantly found in Supracoralline

* Quart. Journ. Geol. Soc. vol. xxxi. p. 197.

beds; and its complete fauna, as given by de Loriol, shows that 17 species are common to lower beds and only 10 to higher. Much therefore might be said for making this Supracoralline; but as there is not much certainty about it, and it has hitherto been placed in the Astartian, it may be left there, with the similar rock at Bourges, for the present. Perhaps it would be preferable to draw the line immediately above this, and include the F_2 F_3 of Pellat with the Grès de Wirvigne. The fossils of the latter approximate closely to the Astartian at Havre. The remainder of the Kimmeridgian is well characterized here; the lower portion, being apparently barren of *Pteroceras*, would be better named after its Ammonite; but the upper part is markedly Virgulian, and corresponds to the mass of the "Lower" Kimmeridge Clay (so-called) of Dorset. In the Pays-de-Bray only this portion is seen.

For the series of deposits which overlie the true Kimmeridgian or Virgulian, and underlie the true Portland beds, the name of BOLONIAN is proposed. It has already been proved* that in the Boulogne area these rocks correspond to what had been hitherto considered an integral portion of the Kimmeridge Clay; and Waagen (35), by separating them as a zone above the Virgulian, came to practically the same conclusion. For the lower portion of them, therefore, which especially differs in lithological character from Kimmeridge Clay, and is of the nature of an episode in its midst, the name of "Bolognian episode" was formerly proposed. A further study of the same series in the basin of Paris shows that elsewhere they are not specially episodal in character, but nevertheless require separation from the Virgulian. The name Portlandian has usually been applied to them; but since it is certain that they do not correspond to our Portland rocks, but to beds below them, this name is to the last degree misleading†; and the only way out of the confusion is the use of a distinct name. Sæmann is said by Pellat (39) to have proposed the name *Pontidian*; but as this is rejected by the latter, who alone mentions it, it cannot be said to have priority; and it is not a good geographical name. It seems therefore best to modify the name already applied, and extend it to all the continental beds which, not being so, have been called Portlandian. Some name connected with the term "Calcaire du Barrois" would have been better, if some true Portland stone had not been included in that term.

These Bolonian beds admit of a twofold subdivision in almost every locality, though the apparently natural limits in the several places may not quite coincide. In the Boulogne area the two parts here distinguished have been called "Lower and Middle Portland." According to Pellat, the fauna of the Lower Bolonian commences in the clays *below* the great conglomerates; hence the change of fauna was not brought about by the changes of physical character, but had already commenced. The palæontological line will therefore not coincide with the lithological one; but the upper parts of the clay series are inde-

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 189.

† Some Swiss geologists have been led by this misnomer to declare that there are no Portland beds (in *their* sense) in the Isle of Portland!

pendently marked off by a change of fauna, and the "Lower Portland" comes in in the midst as a true episode. This episode is less marked in the Pays de Bray, and scarcely recognizable in the coast of Kimmeridge, where we find the northern argillaceous type of the Bolonian, equally marked off from the Virgulian by its fossils. During the same epoch the southern or calcareous type was being developed. The distinctions made in this, of lithographic limestones, carious limestones, and tubular limestones, are too local to be of great importance; but the two zones of *Ammonites gigas* and either of *Pinna suprajurensis* or *Cyprina Brongniarti* are of wider interest. These represent the bulk of the Bolonian in the southern range. It would appear that at Boulogne the argillaceous and calcareous types overlapped for a while, and the palæontological divisions scarcely coincide with the lithological. Hence if we divide the Bolonian into the two parts which have the widest significance, the *Lower Bolonian*, or zone of *Amm. gigas*, will commence with M_2 and end above N_2 of M. Pellat (that is below the Perna-beds); and the *Upper Bolonian* (or zone of *Cyprina Brongniarti* in the south) will include N_3 and N_4—that is, the remainder of the episode, together with argillaceous beds called "Middle Portland." M. Pellat includes N_2 also in the upper zone; but as it contains *Amm. gigas* the reason of this is not evident. The northern type may also be divided palæontologically, independently of the forms which may be supposed introduced from the south. The lower portion appears to be characterized by *Amm. suprajurensis* (formerly quoted as "*A. Thurmanni?*"), and the upper by several species, amongst which it is difficult to choose the most characteristic. *Belemnites Souichii*, *Astarte Sæmanni*, and *Discina latissima* are the chief species almost confined to this portion. These divisions would coincide very nearly with those of the southern range; and if with the zone of *Cyprina Brongniarti* were included the unfossiliferous grey-green limestones of the Meuse and Haute-Marne, the periods might be considered synchronous. This is very nearly the correlation made by Pellat (39, 68); that is, he recognized in the two fossiliferous zones his "Lower Portland," and in the barren zone the possible equivalents of his "Middle Portland." His greatest line of division, however, is at a different place, namely above N_4. This arrangement may be most suitable for Boulogne; but it makes the Upper Bolonian almost absent from the southern ranges, whereas it probably continued there in its varied forms long after the introduction of clay and clay-loving forms into the Boulonnais.

Tracing these beds through the areas of their occurrence, we find only the lower Bolonian or lithographic limestones in the Ardennes and Northern Meuse; and from these the lower portion of the rocks assigned to the same series by Buvignier must be detached, as containing a more Virgulian fauna, especially *Pholadomya acuticostata*. The presence of *Exogyra virgula* itself even in lumachelles cannot be made of any great importance, since at Boulogne, throughout the southern range, and even in England that oyster certainly survived the introduction of a very distinct fauna of far more interest than itself. There is no sign of thinning of the Bolonian beds in the Meuse, as Hébert supposed (21); for, as Buvignier (22) points out, the smaller quantity there visible is composed of the lowest beds only, and not of diminished representatives of all. On entering the Haute-Marne much more is seen, in fact the full development, which, however, commenced near Bar-le-Duc in the extreme limit of the Meuse. The Lower Bolonian will here be the "Lithographic limestones" of Buvignier and the zone of *Ammonites gigas* of Royer and Tombeck, of which, after them, the Bure oolite may be taken as the upper limit *. The Upper Bolonian includes the more fossiliferous beds, distinguished as carious, spotted, and tubulous limestones, and also the lower portion of the series called the zone of *Cyrena rugosa,* namely the porous limestones, which are mostly unfossiliferous, but in places appear to contain *Natica Marcousana*, a very characteristic Bolonian fossil. Passing westwards, the tubulous limestones and higher beds are rapidly lost, and the series is reduced in the valley of the Aube to the Lower Bolonian and the carious limestones. These two are of longer continuance, and are found as fully developed and still more fossiliferous in the valley of the Yonne, while they have representatives as far as Bourges. In the Charente the sandy limestones near Angoulême give us fair representatives of the Lower Bolonian, though with a somewhat uncommon fauna, somewhat allying it to the Upper. This latter must be recognized in the wide-spread limestones with *Cyprina Brongniarti* and other usual fossils of this horizon. Possibly representatives of the Lower Bolonian exist in the Ile d'Oléron, in the limestones at the base with *A. Gravesianus*; but the great mass seen to the south of the harbour of S. Denis is undeniably Upper Bolonian, with the same palæontological characters as in the Charente. Neither in the Orne and Sarthe departments nor in Normandy are beds so high in the series reached. In the Pays de Bray the lowest Upper Jurassic rocks are the Virgulian marls; and above them the Bolonian beds are well developed. These are considered by M. de Lapparent (69) to commence with his "beds with *Ostrea catalaunica*;" while his "upper clays and lumachelles" and "compact lithographic limestones" are referred to the Virgulian. It has, however, been shown that the top of the "lower clays and lumachelles" is exceedingly similar in character to the base of the Lower Bolonian at Boulogne, that in the north these contain the characteristic *Trigonia Munieri,* and in the centre the lithographic limestones contain *Amm. gigas,* while in the south, according to MM. Sæmann and Graves (39, 8), at Hodenc, a locality coloured Portlandian by M. de Lapparent, the upper marls (which are very thin in the north) contain *Amm. gigas* and *Amm. Gravesianus*, and are followed immediately by beds with *Cyprina Brongniarti.* Hence it is more consonant with other localities to commence the Lower Bolonian towards the top of the "lower clays and lumachelles," and end it at the top of the "beds with *Ostrea catalaunica.*" The Upper Bolonian, as before noted, commences with the "calcareous grit with Anomias" and continues to the top

* Perhaps the beds at Cirly recorded by Tombeck to contain *Amm. gigas* and *A. suprajurensis,* ought to be also included in the Lower Bolonian.

of the blue marls called "Middle Portland." The latter undoubtedly correspond to the beds called by the same name at Boulogne; and the grits below represent the upper part of the so-called "Lower Portland," as has been shown by Pellat (46).

In our own country the Bolonian strata are pretty nearly synonymous with those shown to be separable under the title Upper Kimmeridge. Only in the coast-section of Dorsetshire has any distinction into Upper and Lower Bolonian been possible as yet; but when once it is recognized that the whole is argillaceous, the two parts may be some day recognized by their fossils. Throughout the basin of Paris, however, and in the Dorset section, the lower beds are less fossiliferous, and therefore in England they will be less likely to attract attention in inland sections. In separating the Bolonian from the Kimmeridge below and the Portland above, there arises in England, as at Boulogne, the question as to their limits. In the latter place, the "Lower Portland" is taken by Pellat (68) to commence in the midst of marls, on account of the change of fauna. And this change is a remarkable one; for it consists in the introduction of species which do not specially characterize the episodal deposits, but which continue upwards through the whole of the Bolonian. So on the coast of Dorset the lower limit of the Bolonian must also be drawn in the midst of clays, where the most marked introduction of new species commences. This takes place at no very well defined line; so that the limit must remain open; in any case it will be below bed No. 29 of the Kimmeridge Bay section, and may be as low as No. 40. At Boulogne, the "Middle Portland" has been taken to end upwards where the sands cease to be marly and are often consolidated into calcareous grits, the lowest beds of the next series containing a different fauna, the most remarkable species being *Cardium Pellati*. If we draw the same line in England, it will lie immediately beneath the Flinty series of the coast, the Tisbury freestone, the Swindon Trigonia-beds, and the rubbly limestones of Buckinghamshire. In other words, the "Portland Sand" must be thrown into the Upper Bolonian, care being taken that the glauconitic and rubbly beds which form the base of the true Portland are not included. That the sands ought to be separated from the Portland Stone was perceived by Fitton; and their distinctness from the general mass of the Kimmeridge Clay was equally clear to him. The fact of their containing a fauna much allied to that of the higher parts of what was then called the Kimmeridge Clay, enables us rightly to associate the two under a separate and common title, the Bolonian. This period both in England and the North of France, served as an introduction to the Portland, with the lowest beds of which its uppermost strata have several fossils in common.

The localities in England which show Bolonian strata may now be enumerated. In general, of course, all that has been described as Portland Sand will now represent part of the Upper Bolonian, and, in addition, much that has been termed Kimmeridge Clay. The brick-yards at Upway, the fossiliferous beds at the base of the Tisbury section, the sandy "Kimmeridge Clay" of Devizes, so rich in fossils, the sandy portions below the actual sand on the northern slopes of Swindon Hill, the lower part of Shotover Hill with the finely laminated clays, the uppermost part of the pit at Ely, and the whole of the mass called Upper Kimmeridge in Lincolnshire *, all belong to the Bolonian. In most cases no subdivision into Upper and Lower can be traced; but the record by Prof. Judd (Q. J. G. S. vol. xxiv. p. 237) of *Amm. gigas* and *Amm. Gravesianus* in the "Portlandian" portion of the Speeton Clay would appear to indicate the distinctness of the Lower Bolonian in that locality. It appears from this description that the Upper Bolonian in the northern area may be divided into 3 minor parts as in the south, viz. the zone of *Cyprina Brongniarti*, the zone of *Discina latissima*, and the Portland Sands, which last might be called the zone of *Belemnites Souichii*.

The last series to be considered is the Portlandian. The line of junction of this with the Bolonian has already been discussed. The beds above this line which may be certainly placed among Jurassic deposits, are the Flinty Series, the Building-stones, and the Purbecks of the Isle of Purbeck. Towards the close of the Jurassic epoch freshwater conditions appear to have set in in various parts of the area under study. There is, however, no reason to suppose that their introduction in every place was synchronous, but every reason to think the contrary; yet by the custom of calling all these beds "Purbeck" their synchronism has been practically affirmed. To obviate this it is proposed to include the typical Purbecks, as seen in the Isle of Purbeck itself, in a "Portlandian" group, of which it will form the upper member, while the Flinty series and Building-stones form the lower. There can be no objection to this, if it renders correlation easier.

It remains, then, only to indicate the localities where these rocks occur, and their position in the group. In the southern range no possible representative is met with till we reach Bar-le-Duc, shortly before entering the Haute-Marne. Here commences a small mass of rocks formerly considered Suprajurassic, of which the most noteworthy is the vacuolar oolite. From stratigraphical position, this might equally well represent the upper part of the Upper Bolonian; but the occurrence in it of *Astarte rugosa*, a characteristic fossil of true Portland rocks, leads to its being placed as Lower Portlandian, a correlation to which Pellat (68) agrees (using the term in the sense now defined). These beds have been proved (40) to be overlain unconformably by the Neocomian; so that nothing higher is to be found; but it is a remarkable circumstance that the greatest development upwards is just at that locality where all detrital beds are at their maximum, opposite the Straits of Dijon. These beds soon disappear; and nowhere else in the same range can similar beds be found. In the Charente, however, if we correlate the limestones with *Cyprina Brongniarti* (or its representative) with the Upper Bolonian, the succeeding beds with *Corbula inflexa* must be the base of the Lower Portland. Indeed the Portlandian and Bolonian may be

* In the map in Quart. Journ. Geol. Soc. vol. xxxi. p. 202, the names "Upper Kimmeridge" and "Lower Kimmeridge" have been interchanged by error.

here less distinct than elsewhere; for if Coquand is right in recording *Cardium dissimile* from the latter, and the shell called *Astarte rugosa* has been rightly determined from Chassors, there is a very Portlandian aspect even about the Lower Limestone, though it would be impossible, for stratigraphical reasons and from the general character of its fauna, to separate it from the Upper Bolonian. Thus there is nothing to absolutely prevent a geologist from considering, with Coquand (24), that the gypseous beds at the top belong to the Upper Portland, *i.e.* Purbeck; but it is more in keeping with probability to regard them as taking the place, without any intervening gap, of the Lower Portland or true Portland limestone, as Manès does (17) when he groups the equivalent beds in the Ile d'Oléron with those below. In the latter locality, at St. Denis, it is undoubted that beds with *Cardium dissimile* follow very closely on others with *Cyprina Brongniarti* (or its representative); and these we are justified in considering Portlandian. They are followed conformably by the gypseous beds, which are associated with others containing fossils like the beds below; and these too, therefore, are placed as Lower Portlandian. In the Pays de Bray it has been satisfactorily shown that above the Upper Bolonian clays come ferruginous grits containing true *Trigonia gibbosa*; and these are therefore rightly placed by de Lapparent (69) and Sæmann on the horizon of the Lower Portlandian of the present paper. In the Boulonnais the beds hitherto called "Upper Portland" correspond without doubt to the true Portland limestone, but not to the whole of it. Throughout they are more or less arenaceous, and correspond lithologically to the Flinty series, while their characteristic Ammonite is *A. bononiensis*, and not *A. giganteus*, which latter is characteristic of the Building-stones. Here, therefore, the Portland series is incomplete; and the beds which lie at the top and contain *Astarte socialis* and Cyprids are, for this reason, scarcely likely to represent Purbeck beds. They are in fact so rubbly and irregular that they cannot be considered conformable, and may be of any age, either Purbeck or Wealden; but there is not the slightest proof that they belong to the former. Finally, in our own country it has been shown (Q. J. G. S. vol. xxxvi.) that the Portland limestone is only complete in Dorsetshire and the Vale of Wardour; and in these two districts the freshwater (or partially freshwater) strata will belong to the Upper Portlandian, and be its only representatives. Justifications for a closer association of these rocks with the Portland marine limestones than is allowed by calling them Purbeck, may be found in the occurrence in them of *Hemicidaris purbeckensis* in Dorsetshire, a fossil found also in the Upper Bolonian, and of *Trigonia densinoda*, belonging to the *Glabræ*, recently described by Mr. Etheridge (Q. J. G. S. vol. xxxvii. p. 247) in the Vale-of-Wardour "Purbecks." It is true these beds exhibit local unconformities; but that is natural when freshwater strata succeed marine; and it is to be noted that "Purbecks" never lie on any thing but "Portlands." The so-called Purbecks of Swindon and those of Buckinghamshire, lying on lower portions of the Portland limestones, will belong to the Lower Portlandian.

In bringing this Part I. to a close, I must not omit to return my thanks to those who have assisted me; especially to M. de Lapparent, who enabled me to study the literature of the subject in Paris, and who showed me the true Portlandian fossils from the Pays de Bray; to Prof. Hébert, who gave me many valuable indications of the best localities to visit, without which my difficulties would have been greatly increased; to M. Rigaux, who has on several occasions guided me in the Boulonnais; to MM. Cotteau and de Loriol, who have given me copies of some of their writings for reference; and, finally, to the Government-Grant Committee of the Royal Society, to whose recommendation I owe the means of carrying on these researches on the Continent.

EXPLANATION OF PLATE XXVI.

Comparative diagram sections of Upper Jurassic Rocks, Paris Basin and England.

Discussion.

The President stated that the correlations of the author went far to complete our knowledge of the Upper Jurassic rocks in the Anglo-Parisian Basin.

Mr. Hudleston was able to confirm the author's views concerning the correlation of the Upper Jurassic strata in parts of this country with those of the Ardennes as regards the lowest beds in question. The coincidence in the faunas of the beds in these widely separated areas was very remarkable. He thought Mr. Blake's observations tended to support the views of M. Hébert rather than those of M. de Loriol with respect to the importance of the Coral Rag as a formation. He did not agree with the separation of the so-called "Pterocerian;" nor could he agree with the author in absorbing the greater part of the Kimmeridge Clay into his "Bolonian." The author's Bolonian was called by the French authors Lower Portlandian, and was claimed by them as the normal or characteristic deposit; while the Portlandian in the south of England, on a higher horizon, was the less constant development, and therefore more truly the episode.

The Author, in reply to Mr. Hudleston, stated that the Astartian of this country resembled that of Normandy rather than that of the Boulonnais; but he agreed with him as to the Pterocerian. He thought that the calling of the Bolonian by the name of "Portlandian" had been a continual source of error.

39. *A* Descriptive Catalogue *of some of the* Species *of* Ammonites *from the* Inferior Oolite *of* Dorset. By S. S. Buckman, Esq. (Communicated by James Buckman, Esq., F.G.S.) (Read June 22, 1881.)

Before commencing a descriptive catalogue of these Ammonites, it may be as well to give some idea of the various beds from which they come. This has been done before; but, various mistakes having crept in and new researches having given us fresh information, I deem it worth while to reintroduce the subject.

The beds under consideration begin with the "Sands" or "Passage-beds," also called Midford Sands. They are from about 100 to 150 feet, perhaps more, in thickness, with interpolated layers of comminuted shells about a foot or so thick, occurring at intervals of from 4 to 10 feet. These layers contain a large conglomeration of broken shells, so that good specimens are scarce. I have obtained from them a *Rhynchonella* which is probably *R. cynocephala* (Richard.), besides *Harpoceras Moorei* (Lycett), and several species of *Trigonia* (clavellated and costate), *Lima*, *Astarte*, &c.; and I am led to suppose that these sands are probably equivalent to the lower part of the Cynocephala stage of Lycett, in the Cotteswold Hills.

Above these sands comes the stone of the Inferior Oolite. This stone changes at certain levels, both in composition, colour, and hardness. The Ammonites do not occur all in one bed, but this Inferior Oolite stone can be very well divided into four zones, which are extremely well marked, but vary very greatly in thickness at different localities; and it is probably this variation in thickness, and sometimes *almost complete* absence of a zone, that has led to very much confusion.

At the base of the Inferior Oolite Limestone comes the zone of *Harpoceras Murchisonæ*. It rests on a bed of blue stone, which probably belongs properly to the sands.

The bed in which *H. Murchisonæ* occurs is mostly of a light brown colour, sometimes well filled with iron grains, sometimes almost altogether lacking them; it is generally very hard. At Bradford Abbas it is about 1 foot thick, but on Corton Down from 3 to 4 feet.

Above this comes the zone of *Harpoceras Sowerbyi*. This bed is sometimes light yellow with iron grains, sometimes dark blue with similar grains, the light yellow being soft and the dark blue hard. Its range is about 3 feet at Bradford Abbas; and at Halfway House, &c. it is about the same thickness.

Above this comes the zone of *Stephanoceras Humphriesianum*, which is almost entirely, if not quite, absent at Bradford Abbas. At Oborne, however, its thickness is about 5 feet, while at Louse-

Hill and Wyke quarries this zone is only represented by two thin layers very much charged with iron, the two being only about 6 inches thick, but containing nearly all the species that one finds at Oborne in the *Humphriesianum*-zone.

Above this comes the zone of *Cosmoceras Parkinsoni*, which varies very much in different positions. Near Sherborne it is about 15 to 20 feet thick, but very unfossiliferous. At Bradford Abbas it is about 6 feet thick, the upper part having probably been washed away; it is rather unfossiliferous. At Clifton Maybank, however, about 2 miles from Bradford Abbas, a small opening in this zone was made; and it was found highly fossiliferous, while at Broad Windsor, and near Bridport, it contains a *large* number of species and specimens.

I here give sections of three quarries—one at Oborne, the other at Wyke, and the third at Bradford Abbas—to show the different beds clearly.

Fig. 1.—*Section at Oborne, near Sherborne.*

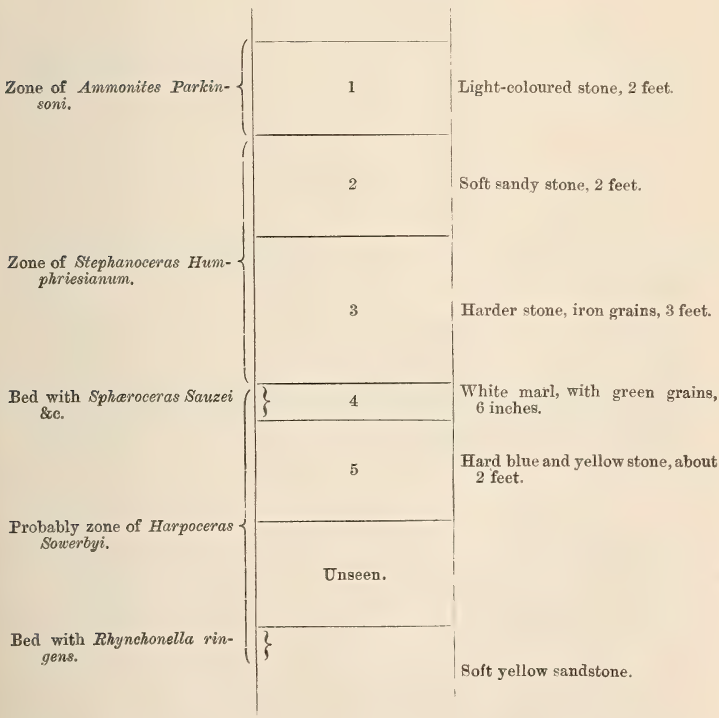


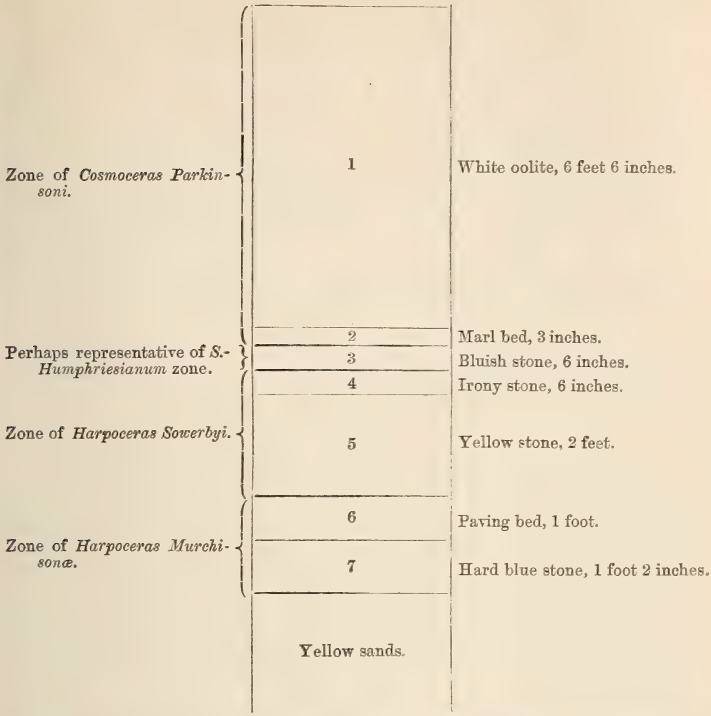
Fig. 2.—*Section at Wyke Quarry.*

Zone of *Cosmoceras Parkinsoni.*	1	Whitish stone, perhaps 20 feet, extending up the hill.
Zone of *Stephanoceras Humphriesianum.*	2	Dark red stone, filled with iron &c., 7 inches.
Zone of *Harpoceras Sowerbyi.*	3 * * * * * * *	Bluish stone, sometimes yellow, with plenty of iron grains, 3 feet 10 inches.
Zone of *Harpoceras Murchisonæ.*	Lower part hidden.	Lighter yellow stone, 2 feet.

Bed No. 2 contains *Stephanoceras Humphriesianum*, *S. Blagdeni*, *S. Braikenridgii*, *Cosmoceras Garantianum*, and many others peculiar to the zone of *Steph. Humphriesianum* at Oborne.

*** Bed with *Rhynchonella ringens*, Hérault.

Fig. 3.—*Section at Bradford Abbas.*



Bed No. 4 is perhaps the representative of the *Sphæroceras-Sauzei* bed at Oborne. Bed No. 2 contains *Terebratula Morieri* and *Rhynchonella parvula.*

The zone of *Harpoceras Murchisonæ* in this district contains :—

Harpoceras Murchisonæ (*Sow.*).
—— ——, var. bradfordiense, *S. S. Buckm.*
Rhynchonella subtetraedra, *Dav.*
—— subdecorata, *Dav.*, young.
Rhynchonella subangulata, *Dav.*
Terebratula perovalis, *Sow.*
Waldheimia anglica (*Oppel*).
Terebratula Etheridgii, *Dav.*
—— simplex, *Buckm.*

The zone of *Harpoceras Sowerbyi* contains :—

Harpoceras Sowerbyi (*Miller*).
—— adicrum (*Waagen*).
—— Levesquei (*d'Orb.*).
—— fissilobatum (*Waagen*).
—— cornu, *S. S. Buckm.*
Lytoceras confusum, *S. S. Buckm.*
Amaltheus subspinatus, *S. S. Buckm.*
Astarte excavata, *Sow.*
—— elegans, *Sow.*
Terebratula Eudesii, *Oppel.*

The *Sphæroceras-Sauzei* bed at Oborne contains :—

Sphæroceras Sauzei (*d'Orb.*).
Stephanoceras polymerum (*Waagen*).
Sphæroceras meniscum (*Waagen*)?
Harpoceras Sowerbyi (*Miller*), var.

The zone of *Stephanoceras Humphriesianum* contains:—

Stephanoceras Humphriesianum (*Sow.*).
Harpoceras cycloides (*d'Orb.*).
Cosmoceras subfurcatum (*Schloth.*).
—— Garantianum (*d'Orb.*).
Haploceras oolithicum (*d'Orb.*).
Harpoceras Edwardianum (*d'Orb.*).
Lytoceras Eudesianum (*d'Orb.*).
Stephanoceras Blagdeni (*Sow.*).
Stephanoceras Braikenridgii (*Sow.*).
—— linguiferum (*d'Orb.*).
Sphæroceras Brongniarti (*Sow.*).
—— Gervillii (*Sow.*).
Stephanoceras Deslongschampsii (*Defrance*).
Cosmoceras Caumontii (*d'Orb.*).
Sphæroceras Wrightii, *S. S. Buckm.*
Oppelia subcostata, *J. Buckman.*
Ammonites cadomensis, *Defrance.*
Perisphinctes Davidsoni, *S. S. Buckm.*
Terebratula sphæroidalis, *Sow.*, abundant.
Astarte obliqua, *Desh.*
Rhynchonella senticosa, *von Buch.*
Terebratula Buckmani, *Dav.*

This *Humphriesianum* zone is the "Fossil Bed" in quarries round Sherborne, where it is so well developed. It has been put down as the equivalent of the *Sowerbyi* zone or "Fossil Bed" (misleading term) of Bradford Abbas and neighbourhood under the name of "the Cephalopoda bed of the Inferior Oolite;" and the extraordinary difference in the species has been attributed to the difference in the *locality*.

The fact is that the *Humphriesianum* zone is almost absent at Bradford Abbas, but is represented near Halfway House by a thin band of ironstone, about 6 inches in thickness, which overlies the *Sowerbyi* zone, and which contains a list of species which agrees with those from the *Humphriesianum* zone at Sherborne; while the *Sowerbyi* zone at Sherborne is often not quarried, and therefore has escaped notice, as it was supposed the quarrymen had reached the sands, as they do at Bradford Abbas. The term "fossil bed," too, was probably answerable for part of the confusion, and shows the necessity for calling beds by the name of some characteristic fossil, and not by some local appellation which may often denote beds at entirely different horizons.

The zone of *Cosmoceras Parkinsoni* contains:—

Cosmoceras Parkinsoni (*Sow.*).
—— Garantianum (*d'Orb.*).
Oppelia Truellii (*d'Orb.*).
—— subradiata (*Sow.*).
Sphæroceras polymorphum (*d'Orb.*).
—— dimorphum (*d'Orb.*).
Perisphinctes Martinsii (*d'Orb.*).
Stephanoceras zigzag (*d'Orb.*).
Terebratula Phillipsi, *Morris.*
—— sphæroidalis, *Sow.*
—— Stephani, *Dav.*
Rhynchonella spinosa (*Schloth.*).
Terebratula globata, *Sow.*, variety?

Besides the Ammonites here mentioned from these four zones, I have separated about 50 more species, which, so far as I am aware, have not yet been described. These rocks are also well stocked with Gasteropoda, of which there are about 150 different species; and Lamellibranchiata are very abundant; of Brachiopoda we have about 40 species made out.

It may be as well before describing the species to explain a few terms made use of in these descriptions.

The *Inner portion of whorl* is that which is nearest to the centre of the Ammonite, otherwise called the dorsal part.

Outer portion is the opposite, otherwise called the ventral area.

Shoulder is where the inner portion of the whorl meets the preceding whorl, and is an important point in the diagnosis of Ammonites; some shoulders are square, as in *Harpoceras Tessonianum* some concave, see *Harp. Murchisonæ*; some convex, some merely sloping, &c.

Termination or mouth-border, i. e. the completion of the body-chamber.

The termination is variously shaped: some have a plain semilunar band, as *Stephanoceras Humphriesianum*; others, *ears* of various shapes, set up either nearly altogether on the ventral area, as in *Steph. Braikenridgii*, or on the sides and projecting straight, as in *Sphæroceras Sauzei* (d'Orb.); others have a termination like an **S**, as *Harpoceras concavum*; this is called the *double* bend; others have this double bend with a horn projecting from the middle others have a *single* bend, like *Amaltheus spinatus* (Bruguière).

In the following Tables I have roughly classified the Ammonite according to their variously shaped terminations:—

1. Semilunar termination.

Stephanoceras Humphriesianum (*Sow.*).	Stephanoceras Deslongschampsii (*Defrance*).
Cosmoceras Garantianum (*d'Orb.*).	Perisphinctes Davidsoni, *S. S. Buckm.*
Stephan. polymerum (*Waagen*).	

2. Semilunar termination, with a deep furrow first, and, sometimes, a raised *lip*.

Sphæroceras Gervillii (*Sow.*).	Sphæroceras Mansellii, *J. Buckm.*
—— Brongniarti (*Sow.*).	—— dimorphum (*d'Orb.*).
—— Wrightii, *S. S. Buckm.*	

3. Spathulate ears, projecting from a little on each side of the ventral area.

Stephanoceras Braikenridgii (*Sow.*).	Perisphinctes Martinsii (*D'Orb.*).
—— Blagdeni (*Sow.*).	

4. Ears like No. 3, but projecting from the side.

Sphæroceras Sauzei (*d'Orb.*).	Stephanoceras linguiferum (*d'Orb.*).

5. Termination, double bend *without* any horn.

Harpoceras concavum (*Sow.*).	Harpoceras cycloides (*d'Orb.*).
—— Murchisonæ, var. bradfordiense, *S. S. Buckm.*	—— adicrum (*Waagen*).
—— Moorei (*Lyc.*).	Haploceras oolithicum (*d'Orb.*).

6. Termination, double bend *with* horn.

Harpoceras cornu, *S. S. Buckm.*	Oppelia subradiata (*Sow.*).
Cosmoceras Parkinsoni (*Sow.*)*.	Harpoceras Levesquei (*d'Orb.*).
Harpoceras Edwardianum (*d'Orb.*).	

* I have placed it here on the authority of d'Orbigny's figures, my own specimen not showing the termination exactly enough.

7. Termination like No. 6, but not produced on ventral area.

Cosmoceras subfurcatum (*Schloth.*). | Cosmoceras Caumontii (*d'Orb.*).

8. Termination, a spathulate ear each side, and one on the ventral area.

Ammonites cadomensis, *Defrance.*

9. Termination, a plain single bend, more or less produced on ventral area.

Amaltheus spinatus (*Bruguière*) in the Lias.
Inf. Oolite. Amaltheus subspinatus, *S. S. Buckm.*
Lytoceras confusum, *S. S. Buckm.*

We will now proceed to give a short notice of the various species of Ammonites recognized in this district.

STEPHANOCERAS HUMPHRIESIANUM (Sow.).

1825. *Ammonites Humphriesianus,* Sow. Min. Conch. pl. 500, middle figure.

1830. *A. Humphriesianus* (Sow.), Zieten, Petref. pl. 67. fig. 2.

1845. *A. Humphriesianus* (Sow.), d'Orb. Pal. Franç. Terr. Jurass. pls. 133, 134, 135. figs. 1, 2.

1849. *A. Humphriesianus* (Sow.), Quenstedt, Ceph. tab. 14. figs. 7, 11; Quenstedt, Jura, pl. 54. figs. 2, 3, 4.

1849. *A. coronatus oolithicus,* Quenstedt, Ceph. tab. 14. fig. 4.

1856. *A. Humphriesianus* (Sow.), Oppel, Juraformation, p. 376, no. 40.

1856. *A. subcoronatus,* Oppel, Juraformation, p. 376, no. 39.

1856. *A. Bayleanus,* Oppel, Juraformation, p. 377, no. 43.

1854. *A. Humphriesianus* (Sow.), Morris, Catalogue, p. 292.

1878. *Stephanoceras Humphriesi* (Sow.), Bayle, Explic. de la Carte Géol. de la France, vol. iv. pl. 51, figs. 2, 3.

1881. *A. Humphriesianus* (Sow.), J. Buckman, Quart. Journal Geol. Soc. vol. xxxvii. p. 65, fig. 6.

Bayle in 'Explication de la Carte Géologique de la France,' vol. iv. plate 51. figs. 2, 3, shows what I take to be a rather peculiar variety of *Stephanoceras Humphriesianum.*

Localities. Oborne, and near Sherborne, Burton Bradstock, and other places: rather common.

Quenstedt, under the name of *Amm. coronatus oölithicus,* figured the young form of the thick variety of this species, which Oppel also mentioned by the name of *subcoronatus.* Oppel also separated the thin form, under the name of *Bayleanus,* observing that it occurred lower than *Humphriesianus* proper. My own observations, however, do not agree with this, as I have found both the thin and thick varieties together; and Mr. D. Stephens assures me that they both occur together at Milborne Wick, the thin variety being the commoner. I have, however, seen the necessity for distinction, and have kept Oppel's names for the varieties, the thick variety being *Stephan. Humphriesianum,* var. *subcoronatum* (Oppel), and the thin *Stephan. Humphriesianum,* var. *Bayleanum* (Oppel).

Stephanoceras Deslongschampsii (Defrance).

1845. *Ammonites Deslongschampsii* (Defr.), d'Orb. Terr. Jurass. pl. 138. figs. 1, 2.
1856. *A. Deslongschampsii* (Defr.), Oppel, Juraform. p. 378, no. 44.
1880. *Stephanoceras Deslongschampsii* (Defr.), Wright, Lias Amm. Palæont. Soc. 1880, p. 224, fig. 116.

Locality. Humphriesianum zone, Oborne: very rare.

The termination of this species is a fine semilunar border. One beautiful specimen showing this was obtained from Oborne by E. Cleminshaw, Esq., F.G.S.

Stephanoceras Blagdeni (Sow.).

1818. *Ammonites Blagdeni*, Sow. Min. Conch. pl. 201.
1818. *A. Banksii* (Sow.), Min. Conch. pl. 200.
1830. *A. coronatus* (Schloth.), Zieten, Verstein. Württemb. tab. i. fig. 1.
1845. *A. Blagdeni* (Sow.), d'Orb. Terr. Jurass. tab. 132.
? *A. coronatus*, Quenstedt, Der Jura, tab. 51. fig. 1.
1849. ? *A. coronatus*, Quenstedt, Ceph. tab. 14. fig. 1.
1854. *A. Blagdeni* (Sow.), Morris, Catalogue, p. 290.
A. Blagdeni (Sow.), Morris and Lycett, Great Ool. Moll. tab. 14. fig. 3.
1856. *A. Blagdeni* (Sow.), Oppel, Juraformation, p. 374, no. 38.
1880. *Stephanoceras Blagdeni* (Sow.), Wright, Lias Ammonites, Palæont. Soc. 1880, p. 251, figs. 157, 158.

Localities. This species occurs in the Humphriesianum zone of Oborne, Sherborne, &c.

Stephan. (*Ammonites*) *Banksii* (Sow.) is merely a very large variety of this species.

Stephanoceras Braikenridgii (Sow.).

1818. *Ammonites Braikenridgii*, Sow. Min. Conch pl. 184.
1845. *A. Braikenridgii* (Sow.), d'Orb. Terr. Jurass. pl. 135. figs. 3–5.
A. Braikenridgii (Sow.), Quenstedt, Der Jura, tab. 54. fig. 5.
A. Braikenridgii (Sow.), ? Morr. & Lyc. Great Ool. Moll. pl. 14. fig. 1.
1854. *A. Braikenridgii* (Sow.), Morris, Catalogue, p. 290.
1856. *A. Braikenridgii* (Sow.), Oppel, Juraformation, p. 377, no. 42.
1880. *Stephanoceras Braikenridgii* (Sow.), Wright, Lias Ammonites, Palæont. Soc. p. 251, figs. 159, 160.
1881. *A. Braikenridgii* (Sow.), J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 62, fig. 3.

Localities. Humphriesianum zone at Oborne, and other quarries near Sherborne.

The termination of this species is a fine ear on each side, as is well shown in d'Orbigny. The length of ears varies very much;

and I have some specimens which very much resemble *Steph. Humphriesianum*, var. *subcoronatum* (Oppel), both in the number of ribs and in other respects, but have short ears.

Stephanoceras linguiferum (d'Orb.).

1845. *Ammonites linguiferus*, d'Orb. Terr. Jurass. pl. 136.

1856. *A. linguiferus* (d'Orb.), Oppel, Juraform. p. 376, no. 40.

Locality. Zone of *Stephan. Humphriesianum* at Oborne: very rare.

I possess one specimen with the termination; it has a small plain ear projecting from the side.

Stephanoceras zigzag (d'Orb.).

1845. *Ammonites zigzag*, d'Orb. Pal. Franç. pl. 129. figs. 9, 10, 11.

1856. *A. zigzag* (d'Orb.), Oppel, Juraformation, p. 378, no. 45.

Of this species there are two forms, a thick and a thin one. They are found, however, in the same bed in the same localities, and are similar in all other respects.

The thick primary ribs, so conspicuous in the small specimens, gradually disappear as the fossil becomes larger, and give place to small rounded primary ribs, which come much closer together, sometimes dividing into secondary ribs, and sometimes passing straight round the ventral area without dividing at all.

Localities. Parkinsoni zone at Broad Windsor, Crewkerne Station, &c.

I have no specimen with the termination; but the body-chamber is very long, as I possess one specimen with a body-chamber nearly one whole whorl in length, and yet it does not show even a sign of the termination.

Stephanoceras polymerum (Waagen).

1867. *Ammonites polymerus*, Waagen, Geogn. Pal. Beiträge, p. (99) 605.

1845. *A. Brongniarti*, d'Orb. (non Sowerby), Terr. Jurass. pl. 137. figs. 1, 2.

1881. *A. Brongniarti*, J. Buckman (non Sowerby), Quart. Journ. Geol. Soc. vol. xxxvii. p. 64, fig. 5.

Locality. This species occurs at Oborne, in a whitish sort of marl, with *Sphæroceras Sauzei*.

In the young state it very much resembles the thin form of *Stephan. Humphriesianum*; but when adult it is far more like a *Sphæroceras*.

Sphæroceras Sauzei (d'Orb.).

1845. *Ammonites Sauzei*, d'Orb. Terr. Jurass. tab. 149.

1856. *A. Sauzei* (d'Orb.), Oppel, Juraformation, p. 375, no. 37.

1867. *A. Sauzei* (d'Orb.), Waagen, Geogn. Paläont. Beiträge, p. (100) 606.

1878. *Sphæroceras contractum*, Bayle (non Sowerby), Explication de la Carte Géol. de la France, vol. iv. pl. 53. figs. 1, 2.

1881. *A. Sauzei* (d'Orb.), J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 62, no. 6.

Localities. Marly bed below the zone of *Stephan. Humphriesianum* at Oborne and near Sherborne: rather scarce.

SPHÆROCERAS BRONGNIARTI (Sow.).

1817. *Ammonites Brongniarti*, Sow. Min. Conch. tab. 184 A. fig. 2.

1845. *A. Gervillii*, d'Orb. (non Sow.), Terr. Jurass. pl. 140. figs. 3–8 (non 1, 2, non Sowerby).

1849. *A. Brongniarti* (Sow.), Quenstedt, Ceph. tab. 15. fig. 9.

1856. *A. Brongniarti* (Sow.), Oppel, Juraform. p. 375, no. 35.

1867. *A. Brongniarti* (Sow.), Waagen, Geogn. Pal. Beiträge, p. (96) 602.

1878. *Sphæroceras Brongniarti* (Sow.), Bayle, Explic. de la Carte Géologique de la France, pl. 53. figs. 3, 4, 5.

Localities. Humphriesianum zone at Oborne, near Sherborne, &c. Rather common.

The species that I have placed under this name is the one figured by Sowerby with the closed umbilicus; and the other I have called *Sphær. Gervillii.* I do this because most authorities have so taken it; d'Orbigny, however, transposed them, whether rightly or not I am unable to say without seeing Sowerby's original specimens. There seems to have been some misprint or confusion with regard to them in Sowerby's work.

SPHÆROCERAS GERVILLII (Sow.).

1817. *Ammonites Gervillii*, Sow. Min. Conch. pl. 184 A. fig. 3.

1849. *A. Gervillii* (Sow.), Quenstedt, Ceph. tab. 15. fig. 11.

1856. *A. Gervillii* (Sow.), Oppel, Juraform. p. 375, no. 36.

1867. *A. Gervillii* (Sow.), Waagen, Geogn. Paläont. Beiträge, p. (99) 605.

1878. *Sphæroceras Gervillii* (Sow.), Bayle, Explic. de la Carte géologique de la France, pl. 53. figs. 6, 7.

1881. *A. Gervillii* (Sow.), J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 63, fig. 4.

Localities. Humphriesianum zone at Oborne, near Sherborne, &c. Not so common as *Sphær. Brongniarti.*

SPHÆROCERAS MENISCUS (Waagen)?

1867. *Ammonites meniscus*, Waagen, Geogn. Paläont. Beiträge, p. (96) 602.

1875. *A. Gervillii*, d'Orb. pars (non Sowerby), pl. 140. figs. 1, 2.

Mr. E. Cleminshaw found one specimen at Oborne in the *Sauzei* bed, which I have referred to this species.

SPHÆROCERAS MANSELLII (J. Buckman).

1881. *Ammonites Mansellii*, J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 64, no. 18.

This species, when young, is extremely like *Sphær. Brongniarti* (Sow.), plate 184 A. fig. 2, but when larger is easily distinguished by its very fine and numerous bifurcating ribs and its very square ventral area, especially just by the termination, and its far greater breadth. It also attains a larger size than *Sphær. Brongniarti*. The termination is also peculiar—first a small lip, then a deep furrow, then another lip and band.

This species was named but not figured by Mr. J. Buckman in his paper read before the Geological Society.

Dimensions. Diameter 1·75 inch; umbilicus 0·33; aperture across 1·20; aperture back to front 0·45.

Locality. Clatcombe, near Sherborne. Two fine specimens were obtained from this place by T. C. Maggs, Esq. I do not know of any other specimens.

SPHÆROCERAS POLYMORPHUM (d'Orb.).

1845. *Ammonites polymorphus,* d'Orb. Terr. Jurass. pl. 124. figs. 1, 2, 3, 4, 5? 6?

1849. *A. Parkinsoni inflatus*, Quenstedt, Ceph. Tab. ii. figs. 6 and 7.

1854. *A. polymorphus* (d'Orb.), Morris, Catalogue, p. 294.

1856. *A. polymorphus* (d'Orb.), Oppel, Juraform. p. 382.

We have undoubtedly found in this neighbourhood specimens which exactly correspond with those figured by d'Orbigny, 'Terrains Jurassiques,' pl. 124. figs. 1, 2, 3, 4; but we have not found any to correspond with figs. 5 and 6; and I have my doubts about figs. 5 and 6 really being the adult form of the others. Oppel, too, in quoting *A. polymorphus*, d'Orb., leaves out nos. 5 and 6 (see Oppel, 'Juraformation,' p. 382, no. 54).

Localities. Zone of *Cosmoceras Parkinsoni* at Broad Windsor, Burton Bradstock, and other places.

SPHÆROCERAS DIMORPHUM (d'Orb.).

1845. *Ammonites dimorphus*, d'Orb. Terr. Jurass. pl. 141.

1854. *A. dimorphus* (d'Orb.), Morris, Catalogue, p. 291.

This species varies somewhat in the width of its umbilicus. Some specimens have the umbilicus nearly closed, while others of the same size have the umbilicus much larger, so that a portion of the inner whorls can be seen.

In the adult form the umbilicus widens rather quickly, as is well shown by d'Orbigny, pl. 141. fig. 1.

The variety represented by d'Orbigny (pl. 141. figs. 3 and 4) has, so far as I know, not yet been obtained from this district.

I possess only one specimen with the termination. It is a form with a rather wide umbilicus. The termination is merely a small furrow and a semilunar lip beyond. The specimen came from Bradford Abbas.

Localities. Zone of *Cosmoceras Parkinsoni* at Halfway House, Broad Windsor, Stoford, and other places.

Sphæroceras Wrightii, S. S. Buckman, n. sp.

1849. *Ammonites microstoma*, Quenstedt (non d'Orbigny), Cephalopoda, tab. 15. fig. 6.

Localities. Humphriesianum zone, Oborne, and near Sherborne: common.

This species was figured by Quenstedt under the name of *A. microstoma*; but it does not at all agree with the figure of *A. microstoma* given by d'Orbigny (who named it) in 'Terr. Jurassiques.'

Dimensions. Diameter, adult, 1·59 inch; umbilicus 0·55 inch; umbilicus, omitting the last chamber, 0·22 inch; breadth, same place, 0·85 inch; breadth across termination 0·79 inch; termination, from back to front, 0·50 inch.

Length of body-chamber very nearly one whole whorl.

Named in compliment to Dr. Wright, of Cheltenham, who is so ably working at the Lias Ammonites.

Cosmoceras Parkinsoni (Sow.).

1821. *Ammonites Parkinsoni*, Sow. Min. Conch. pl. 307.

1845. *A. Parkinsoni* (Sow.), d'Orb. Ter. Jurass. pl. 122, variety.

1849. *A. Parkinsoni gigas*, Quenstedt, Ceph. tab. ii. fig. 1 (adult form).

1854. *A. Parkinsoni* (Sow.), Morris, Catalogue, p. 294.

1856. *A. neuffensis*, Oppel, Juraformation, p. 378, no. 48.

1856. *A. Parkinsoni* (Sow.), Oppel, Juraformation.

1849. *A. Parkinsoni depressus*, Quenstedt, Ceph. tab. ii. fig. 5.

1878. *Parkinsonia Parkinsoni* (Sow.), variety, Bayle, Exp. de la Carte géol. de la France, vol. iv. pl. 67. figs. 2, 3.

1878. *Parkinsonia neuffensis*, Bayle?, pl. 67. fig. 1.

This species is somewhat variable, and has been much misunderstood. The figures given by d'Orbigny ('Terr. Jurass.' pl. 122. figs. 1 & 2) are evidently of a variety of Sowerby's species. This same variety is again figured by Quenstedt under the name of *A. Parkinsoni depressus*; and as such it was quoted by Oppel ('Juraformation') as a synonym for *Parkinsoni*. It was also figured by Bayle under the name of *Parkinsonia Parkinsoni* (see synonyms).

This variety differs from Sowerby's type in having far fewer ribs, far less inclusion (consequently the whorls are not so broad from front to back), and in possessing rather marked tubercles.

To this variety I give the name of *Cosmoceras Parkinsoni*, var. *rarecostatum*, S. S. Buckman.

The fragment figured by Quenstedt (Ceph. tab. ii. fig. 1) under the name of *Ammonites Parkinsoni gigas* is merely the very adult form of the true *Parkinsoni*; and this adult form occurs at Half-way House of very large size, one specimen measuring 19 inches across, and yet lacking a large portion of the outer chamber. This adult form was named by Oppel *Ammonites neuffensis*, he giving Quenstedt's figure as a reference. Bayle has also figured a specimen as *Am. neuffensis*; but I consider that his figure most probably represents merely a rather fine-ribbed variety of a medium-sized true *C. Parkinsoni*.

The true *C. Parkinsoni* occurs in great numbers at Halfway House, also at Bradford Abbas, Burton Bradstock, and Sherborne.

The variety *rarecostatum*, S. S. Buckm., occurs in the same beds at Sherborne, Bradford Abbas, Burton Bradstock, Broad Windsor, &c., but is not so common.

Cosmoceras Parkinsoni is characteristic of the upper beds of the Inferior Oolite. The very adult forms lose all their ribs and also the division on the ventral area, and are very different from the ordinary young form which was figured by Sowerby.

Bayle has separated this species from the genus *Cosmoceras* under the generic name of *Parkinsonia*. I am rather of opinion that it, and also *Cosm. Caumontii* (d'Orb.), should be so separated.

The termination of this species is somewhat produced on the ventral area. I possess one specimen with the termination on the outer half of the whorl well shown, but am unable to say whether the species possesses a horn on the side, or merely a plain double curve. *Length of body-chamber* $\frac{5}{8}$ of a whorl.

Cosmoceras Caumontii (d'Orb.).

Ammonites Caumontii, d'Orb. Terr. Jurass. pl. 138. figs. 3, 4.

Locality. It occurs at Oborne in the zone of *Stephan. Humphriesianum*, but is scarce.

The termination is merely a small, very thin, narrow ear.

Cosmoceras Garantianum (d'Orb.).

1845. *Ammonites Garantianus*, d'Orb. Terr. Jurass. pl. 123.
1849. *A. Parkinsoni dubius*, Quenstedt, Ceph. tab. ii. fig. 9.
1854. *A. Garantianus* (d'Orb.), Morris, Catalogue, p. 292.
1856. *A. Garantianus* (d'Orb.), Oppel, Juraformation, p. 381, no. 53.

Localities. *Humphriesianum* zone, and less commonly in the lower part of the *Parkinsoni* zone, Oborne, Louse Hill, Wyke: rather common.

The termination is a semilunar band.

Cosmoceras subfurcatum (Schlotheim).

1830. *Ammonites subfurcatus* (Schlotheim), Zieten, Verst. Württemb. pl. vii. fig. 6.
1845. *A. niortensis*, d'Orb. Terr. Jurass. pl. 121. figs. 7–10.
1849. *A. Parkinsoni bifurcatus*, Quenstedt, Ceph. tab. ii. fig. 11.
1856. *A. subfurcatus* (Zieten), Oppel, Juraform. p. 381, no. 52.

Zieten figures this species, giving Schlotheim as the authority for the name.

Zieten's figure shows a fossil with a large number of bifurcating ribs, which is the exception and not the rule, this species usually having very few bifurcating ribs, as is shown by d'Orbigny, who figured it under the name of *A. niortensis*.

[There is also a fossil, of which a few specimens have occurred at Oborne, which is probably a variety of this species. It has very much the shape &c. of *Cosmoceras subfurcatum*, and is ornamented with four rows of sharp spines, just where they occur in *Cosm. subfurcatum*; but it is entirely destitute of ribs.]

Locality. Higher part of the *Humphriesianum* zone at Oborne.

The termination is a spathulate ear, slightly wider towards the extremity.

Morris, in his Catalogue, put this species down as a synonym of *Cosmoceras Parkinsoni*; but it is quite distinct from it, especially in its mode of volution. It also occurs lower, viz. in the zone of *Stephan. Humphriesianum.*

Lytoceras Eudesianum (d'Orb.).

Ammonites Eudesianus, d'Orb. Terr. Jurass. pl. 123.

A. Eudesianus (d'Orb.), Quenstedt, Der Jura, tab. 54. fig. 8.

A. Eudesianus (d'Orb.), Oppel, Juraformation, p. 373, no. 29.

This species was for a long time put down for the Inferior Oolite of this district by the name of *A. cornucopiæ*, Young.

Locality. It occurs in the zone of *Stephan. Humphriesianum* at Oborne, but is rare.

Lytoceras torulosum (Schübler)?

Ammonites torulosus (Schübler), d'Orb. Terr. Jurass. pl. 102. figs. 1, 2.

I have one fragment from the sands near Bridport, but am not quite certain if it belongs to this species.

Lytoceras confusum, S. S. Buckman, n. sp.

Syn. ? *Ammonites jurensis*, Morris, Catalogue, p. 292.

This species approaches nearly to *Lytoceras jurense* (Zieten), and has been quoted from this district under that name. It, however, differs from it in a great number of points—namely, the shape of the aperture, which is nearly trianglar, in the very square shoulder, in the number of whorls, and the lobes, which are more complicated than in *L. jurense* (Zieten). Inclusion is small. The test is quite plain, but has a few marked lines of growth in the young form, which also has not the peculiar square shoulder much marked.

In occurs in the *Sowerbyi* zone at Bradford Abbas, Halfway House, Bradford Abbas railway-cutting, &c.

At Half-way House the specimens are of an enormous size, one measuring as much as 17 inches in diameter.

The species is somewhat abundant; but small specimens are very rare.

I have one small specimen, from Bradford Abbas, with the termination. It is a plain bend forward towards the ventral area.

Dimensions. *Young form*, diameter 1·25 inch; umbilicus 0·43 inch; aperture, length 0·47 inch, breadth 0·40 inch; inclusion about 0·03 inch.

Adult form, diameter 15·90 inches; umbilicus 7·20 inches; aperture, back to front, 4·50 inches, across about $5\frac{1}{4}$ inches, inclusion 0·80 inch.

The aperture is, as nearly as possible, an equilateral triangle with a small piece out, caused by the inclusion. The ventral area, however, is a good deal rounded.

PERISPHINCTES PYGMÆUM (d'Orb.).

Ammonites pygmæus, d'Orb. Terr. Jur. pl. 129. figs. 12, 13.

I have one specimen of this species from the neighbourhood.

PERISPHINCTES MARTINSII (d'Orb.).

1845. *Ammonites Martinsii*, d'Orb. Terr. Jurass. pl. 125.
1854. *A. Martinsii* (d'Orb.), Morris, Catalogue, p. 293.
1856. *A. Martinsii* (d'Orb.), Oppel, Juraformation, p. 387.

Localities. Zone of *Cosmoceras Parkinsoni* at Halfway House, Bradford Abbas, Sherborne, and Burton Bradstock, but is rather scarce.

[At Oborne, in the *Humphriesianum* zone, we find a very thin *flat* Ammonite with the furrows well marked. It is far more involute than *Perisphinctes Martinsii*, the amount of involution being nearly half the preceding whorl. It has a semilunar mouth-border, which projects well forward on the ventral margin.

It has hitherto been put down as the same as *P. Martinsii*; but I feel certain that it should be separated as distinct from it, both on account of its stratigraphical position and also its lobes and other features. I propose for it the name *Perisphinctes Davidsoni*, in compliment to Thos. Davidson, Esq., F.R.S.]

I have one specimen of *Perisph. Martinsii*, d'Orb., with the termination. It has two long ears, the inner edges of which project well forward till they touch the inner whorl. This termination is well represented by d'Orbigny, Terr. Jurass. pl. 125. fig. 1. The termination represented in fig. 3 may possibly have been taken from a specimen of *Perisph. Davidsoni*, S. S. Buckm.

HARPOCERAS SOWERBYI (Miller).

1821. *Ammonites Sowerbyi* (Miller), Sow. Min. Conch. tab. 213.
1821. *A. Brownii*, Sow. Min. Conch. tab. 263. figs. 4, 5.
1845. *A. Sowerbyi* (Miller), var., d'Orb. Terr. Jurass. pl. 119.
1849. *A. Sowerbyi* (Miller), Quenstedt. Ceph. p. 374.
1854. *A. Sowerbyi* (Miller), Morris, Catalogue, p. 295.
1867. *A. Sowerbyi* (Miller), var., Waagen, Geogn. Paläont. Beiträge, pl. 27. fig. 2.
1856. *A. Sowerbyi* (Miller), Oppel, Juraformation, p. 369, no. 20.

The figure given by d'Orbigny, pl. 119, represents a variety of this species, and it differs from it in several points. Waagen has also figured, pl. 27. fig. 6, a peculiar variety.

Localities &c. Harpoceras Sowerbyi is a scarce fossil, the species which has been put down by that name as occurring in this district being really *Harp. adicrum* (Waagen). The chief characteristics of *Harp. Sowerbyi* are a very large keel, and sides which slope in gradually to join the inner whorl. It occurs at Sherborne and Bradford Abbas, but is rare.

The variety figured by d'Orbigny occurs at Bradford Abbas, but is also rare.

Harpoceras adicrum (Waagen).

1867. *Ammonites adicrus*, Waagen, Geogn. Pal. Beiträge, pl. 25. fig. 7.

Localities. Zone of *Harpoceras Sowerbyi* at Bradford Abbas, Halfway House, Louse Hill, and many other places; rather abundant. This species often attains a very large size.

Dr. Waagen has very properly separated this species from *Harpoceras Sowerbyi* (Miller). It is sometimes rather difficult to separate it from some of the varieties of that species; but it is really distinct in possessing a small rounded keel, as opposed to the large sharp one of *Harp. Sowerbyi*, also a larger umbilicus and large distinct ribs, when adult, at a time when *Harp. Sowerbyi* is smooth.

Harpoceras fissilobatum (Waagen).

Ammonites fissilobatus, Waagen, Geogn. Pal. Beiträge, pl. 27. fig. 1.

Locality. This species occurs at Sandford-Lane quarry near Sherborne. I believe it is in the zone of *Harpoceras Sowerbyi*; but I have never seen this quarry worked. It is a common fossil there.

Harpoceras concavum (Sow.).

1812. *Ammonites concavus*, Sow. Min. Conch. pl. 94. fig. 2.

1881. *A. concavus* (Sow.), J. Buckman, "Terminations of Ammonites," Quart. Journ. Geol. Soc. vol. xxxvii. p. 60, fig. 1.

Localities. This species is common in the *Sowerbyi* zone at Bradford Abbas, Halfway House, Sherborne, &c.

The termination is a curve like an S; that is, it rises from the inner whorl, curving forward, then rounded and curving back, and then produced on the ventral area. It has no horn, as was supposed when it was figured in the Geological Journal. The species that d'Orbigny has figured by this name (Terr. Jurass. pl. 116) does not seem to me at all to agree with Sowerby's figure.

Harpoceras Murchisonæ (Sow.).

1829. *Ammonites Murchisonæ*, Sow. Min. Conch. tab. 550.

1825. *A. corrugatus*, Sow.? Min. Conch. tab. 451. fig. 3.

1830. *A. Murchisonæ* (Sow.), Zieten, Verstein. Württemb. tab. vi.

1845. *A. Murchisonæ* (Sow.)?, d'Orb. Terr. Jurass. pl. 120. figs. 1, 2, 3, var.?

1854. *A. Murchisonæ* (Sow.), Morris, Catalogue, p. 293.

1856. *A. Murchisonæ* (Sow.), Oppel, p. 368, no. 18.

1867. *A. Murchisonæ* (Sow.), Waagen, Geogn. Pal. Beiträge, p. (92) 598, § 31.

1878. *Ludwigia Murchisonæ* (Sow.), Bayle, Carte. Géolog. de la France, pl. 85.

Localities. This species marks a distinct zone, which is just on the top of the sands or passage-beds. This zone is about a foot thick at Bradford Abbas, but about 3–4 feet at Corton and Hawthorn Downs. *Harpoceras Murchisonæ* occurs at Bradford Abbas, Marston Road, Corton and Hawthorn Downs, and other places, and also rather plentifully, but badly preserved, at Haselbury.

There is a variety (?) which I am inclined to think should be separated from *Harp. Murchisonæ.* It has a smallish umbilicus and very fine ribs, and is far thinner. I have given it the name of *Harpoceras Murchisonæ*, var. *bradfordiense*, S. S. B.

Dimensions of a medium-sized specimen of *Harp. Murchisonæ* :— Diameter 2·85 inches, umbilicus 0·96, breadth of aperture 0·70; outer whorl, back to front, 1·20 inch.

Harpoceras cycloides (d'Orb.).

1845. *Ammonites cycloides.* d'Orb. Pal. Franç. Terr. Jurass. pl. 121. figs. 1–6.

1856. *A. cycloides* (d'Orb.), Oppel, Juraformation, p. 370.

1867. *A. cycloides* (d'Orb.), Waagen, Geogn. Pal. Beiträge, p. (92) 598.

Localities. Humphriesianum zone at Oborne and quarries near Sherborne, somewhat plentiful; also at Wyke Quarry, but scarce.

A variable species, some specimens being very thick, with a small umbilicus and coarse ribs, and others thin, with larger umbilicus and smaller ribs. The two varieties, however, merge one into the other.

D'Orbigny has well represented the two extreme forms.

This species was formerly quoted by the name of *Amm. Cadomensis*, on account of the misprint underneath d'Orbigny's plate.

Harpoceras Levesquei (d'Orb.)?

Ammonites Levesquei, d'Orb. Terr. Jurass. pl. 60 (misprinted *solaris*, Phillips).

I quote this species with some hesitation, as our specimens seem to have fewer whorls and somewhat more marked ribs.

Our specimens are from the zone of *Harpoceras Sowerbyi* at Bradford Abbas, Halfway House, &c.; not very common.

Harpoceras Edouardianum (d'Orb.)?

1845. *Ammonites Edouardianus*, d'Orb. Terr. Jurass. pl. 130. figs. 3–5.

1856. *A. Edouardianus* (d'Orb.), Oppel, Juraformation, p. 370.

1881. *A. Edouardianus* (d'Orb.), J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 61, no. 3.

Our specimens do not seem to agree very well with d'Orbigny's figures, and are perhaps not the same. They have a more open umbilicus and far less inclusion; consequently the whorls are less across.

Locality. Humphriesianum zone at Oborne: scarce.

HARPOCERAS DISPANSUM (Lycett).

My authority for this name is a specimen sent by Dr. Lycett, labelled "*Am. dispansus*, Lyc., Frocester Hill."

I have one specimen from near Crewkerne which agrees very well with it.

HARPOCERAS MOOREI (Lycett).

Ammonites Moorei, Lyc. Cotteswold Hills, pl. 1. fig. 2.

A. Moorei (Lyc.), J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 65, fig. 7.

Localities. Found in layers of comminuted shells in the sands at Bradford Abbas, Yeovil Junction, &c.: not very common.

Termination. A slight double curve produced on the ventral area.

HARPOCERAS CORNU, S. S. Buckman, n. sp.

Ammonites subradiatus, J. Buckman (non Sowerby), "Terminations of Ammonites," Quart. Journ. Geol. Soc. vol. xxxvii. p. 61, fig. 2.

This species is compressed, with strongly marked ribs, which are slightly reflexed and not so prominent close to the termination. They seldom bifurcate; but now and then a rib comes in between which is not continued all across.

Keel distinct, with very sloping sides.

Aperture sagittate.

The *umbilicus* varies somewhat in width; it is, however, rather wide, with strongly marked ribs, showing also a certain portion of each whorl.

Shoulder concave.

Termination. Like that of *Harpoceras concavum* (Sow.); but it has a very long horn on each side.

Difference. This species resembles *Harp. concavum*, but is distinct on account of the horn which the termination possesses, and which I I have never seen in that species. The ribs are also far more marked, and the umbilicus is far wider.

This species never attains the same size as *H. concavum*; but very small specimens of these two species are hard to separate.

This species might possibly be mistaken for the young of *Harpoceras Murchisonæ* (Sow.); it, however, never attains the size of *H. Murchisonæ*, is found at a *higher* level, has a more prominent keel, is far thinner towards the keel, is more acute, and its ribs are less prominent and rather more rounded.

Dimensions. Diameter 2·50 inches, umbilicus 0·60, breadth of aperture 0·48, outer whorl from back to front 1·15. Another specimen measured—diameter 2·70 inches, umbilicus 0·82, breadth of aperture 0·50, outer whorl from back to front 1·06, length of horns 0·65.

I have never seen a specimen of this species which exceeded the diameter of about $2\frac{3}{4}$ inches.

Compare these measurements with those of a *medium-sized Harp. Murchisonæ* (Sow.).

Remarks. This species was figured in the 'Quarterly Journal of the Geological Society' for February 1881, under the name of *Ammonites subradiatus*; but it is very distinct from that species, the umbilicus alone being sufficient to distinguish it.

Localities. It is found in the zone of *Harpoceras Sowerbyi* at Bradford Abbas, Halfway House, and many other places. It is tolerably common.

AMALTHEUS SUBSPINATUS, S. S. Buckman, n. sp.

This species is so peculiar and distinct from all others which I have met with in the Inferior Oolite, that I think it worth while to mention it here, although it has not been figured.

It is very nearly allied to *Amaltheus spinatus* (Bruguière) of the Marlstone. It possesses the peculiar crenulated keel, which is distinct; but the crenulations are not very prominent. It has a large number of whorls, and very small inclusion, but does not increase in breadth at all rapidly. It has many fine angular ribs, ornamented with two spines on each rib, one set being in much the same place as those on *Amaltheus spinatus,* while the other set is on the inner portion of the whorl.

Aperture. Quadrangular.

Dimensions. Diameter 3 inches, umbilicus 1·55, aperture from back to front 0·75, across 0·67, inclusion barely any.

Localities. It occurs in the *Sowerbyi* zone at Bradford Abbas, Halfway House &c., but is scarce.

The termination is like that represented by d'Orbigny (Terr. Jurass. pl. 52. fig. 1) for *Amaltheus spinatus*—a plain single bend, much produced on the ventral area.

OPPELIA TRUELLII (d'Orb.).

1845. *Ammonites Truellii,* d'Orb. Terr. Jurass. pls. 117, 129. figs. 1, 2.

1849. *A. Truellii* (d'Orb.), Quenstedt, Jura, tab. 54.

1854. *A. Truellii* (d'Orb.), Morris, Catalogue, p. 295.

1878. *Oppelia Truellii* (d'Orb.), Bayle, Géologie de la France, vol. iv. pl. 89. figs. 1, 3, 4 (2?, 5?).

Occurs in the zone of *Cosmoceras Parkinsoni* at Halfway House, Wyke Quarry, and Burton Bradstock.

The longitudinal lines well distinguish this species. It is also ornamented with longitudinal furrows, which vary slightly in depth, as also does the species in thickness.

OPPELIA SUBRADIATA (Sow.).

1825. *Ammonites subradiatus,* Sow. Min. Conch. pl. 421. fig. 2.

1845. *A. subradiatus* (Sow.)?, d'Orb. Terr. Juras. pl. 129. fig. 3.

1854. *A. subradiatus* (Sow.), Morris, Catalogue, p. 295.

1856. *A. subradiatus* (Sow.), Oppel, Juraformation, p. 372, fig. 26.

Localities. Zone of *Cosmoceras Parkinsoni* at Broad Windsor, Crewkerne Station, Bridport, &c.: rather common.

Termination from the inner whorl nearly straight, then a rather fine horn, then a curve back, and produced on the ventral area.

OPPELIA SUBCOSTATA (J. Buckman).

1881. *Ammonites subcostatus*, J. Buckman, Quart. Journ. Geol. Soc. vol. xxxvii. p. 63, no. 8.

1845. *A. subradiatus*, d'Orbigny (non Sowerby), Terr. Juras. pl. 118. figs. 1, 2.

This species was figured by d'Orbigny as the large form of *Oppelia subradiata* (Sow.); but I am convinced that it is distinct. It has a far larger umbilicus, coarser ribs, hardly a distinct keel, and is far thicker.

Localities. Zone of *Stephan. Humphriesianum* at Oborne &c.: rather scarce.

HAPLOCERAS OOLITHICUM (d'Orb.).

1845. *Ammonites oolithicus*, d'Orb. Terr. Jurass. tab. 126. figs. 1–4.

1854. *A. oolithicus* (d'Orb.), Morris, Catalogue, p. 294.

1856. *A. oolithicus* (d'Orb.), Oppel, Juraformation, p. 573, no. 32.

Localities. It occurs in the *Humphriesianum* zone at Oborne and Milborne Wick. Our specimens have a slightly smaller umbilicus than those figured by d'Orbigny, but are exactly similar in all other respects.

AMMONITES CADOMENSIS, Defrance.

1845. *Ammonites cadomensis* (Defrance), d'Orb. Terr. Jurass. pl. 129. figs. 9–11.

I am not certain to what genus to attribute this species.

Localities. This species occurs in the zone of *Stephan. Humphriesianum* at Oborne. It is rare. A few specimens possess the peculiar termination. I have one specimen with it from Wyke Quarry, and others from Oborne.

It may be also interesting to add that we have found the following species of *Ancyloceras* &c. in the Inferior Oolite:—

Ancyloceras annulatum, d'Orb. Terr. Jurass. pl. 225. figs. 1–7.
Humphriesianum zone at Oborne.

Anc. subannulatum, d'Orb. Terr. Jurass. pl. 225. figs. 12–15.
Humphriesianum zone at Oborne.

Anc. bifurcatum, Quenstedt; syn. *Hamites bifurcatus*, Quenstedt, Ceph. tab. 11. fig. 15.
Humphriesianum zone at Oborne.

Anc. bispinatum, d'Orb.? Terr. Jurass. pl. 228. figs. 6–9.
It much resembles this species, but is from the top of the *Humphriesianum* zone near Halfway House, and may be new.

Toxoceras Orbignyi (Baugier and Sauzé), d'Orb. Terr. Jurass. pl. 232. figs. 1, 2.

From near Sherborne.

Since the above paper was written, we have made out the Yeovil sands more clearly from some fresh sections. Just below the *Murchisonæ* zone (the equivalent of the Gloucestershire Pea-grit) come about 30 feet of sands. Then comes a marly bed about a foot thick, containing *Harpoceras opalinum*, *Lytoceras torulusum*, *Waldheimia anglica*, and *Rhynchonella cynocephala*. Below this come about 100 feet, sometimes more, of sands in which *Lytoceras jurense* (Zieten) occurs along with *Harpoceras Moorei* (Lyc.) &c. These lower sands therefore belong to the zone of *L. jurense*.

On the vexed question as to whether these latter belong to the Lias or Oolite I have not formed an opinion.

Discussion.

The President bore testimony to the great industry and skill shown by the young author in collecting from the richly fossiliferous beds of the Inferior Oolite of Dorsetshire. He pointed out the importance of having sections of perfect specimens of Ammonites made, so as to show the relation of the body-chamber to the others in these shells.

Mr. Hudleston referred to the difference between the views of Mr. S. Buckman and his father, Prof. Buckman, as to the value of the zones of the Inferior Oolite and the geological age of the Yeovil Sands.

Mr. Charlesworth remarked on the absence of phragmocones of Belemnites in Chalk rocks, and of the opercula of Ammonites from many Jurassic rocks.

Prof. Seeley denied the universal absence of phragmocones of Belemnites in the Chalk, and stated that it might be accounted for by the condition of preservation of the fossils. In the same way the absence of aptychi might be accounted for by the general explanation of such facts given by Mr. Sorby, who showed that fossils composed of the unstable substance aragonite were rarely preserved.

Prof. Blake thought that many of the so-called species of Ammonites would prove to be only varieties of well-known ones. He confirmed the views of the President as to the value of determining the proportion of the body-whorl.

The President stated that Mr. Buckman had adopted the views of classification which he had himself long ago insisted on. He accounted for the frequent absence of aptychi by the fact that the body-chamber is not usually broken open. He also agreed with Mr. Charlesworth as to the general but not universal absence of the phragmocone in *Belemnitella*, and with Mr. Blake that many of these Ammonite-forms could not be regarded as distinct species.

40. Notes *on the* Diamond-fields, South Africa, 1880. By E. J. Dunn, Esq. (Communicated by Prof. Ramsay, F.R.S., F.G.S.) (Read June 22, 1881.)

The mining-operations carried on during the last few years at the diamond-fields, South Africa, have brought to light some additional facts bearing on the formation of diamonds*; the most interesting is the exposure, at all the old mines (Kimberley, De Beer's, Du Toit's Pan, and Bultfontein), of considerable deposits of black carbonaceous shale underlying the surface beds of grey shale.

By the removal of the diamond-bearing ground of the old volcanic "pipes" constituting the above mines, the wall or rim is left unsupported; after rain immense masses of this shale, or "reef," as miners term it, fall into the excavated gulf, leaving excellent clean sections of the horizontal strata; for the bedding of the shales is horizontal, except where locally disturbed by intrusive rocks, or at the sides of the "pipes," where they are turned upwards for a few feet, perhaps by the gabbro in the "pipes."

At Kimberley mine the surface-shales, grey or, in places, pink or yellow, which contain remains of small Saurians, are from 40 to 50 feet thick; underneath are black carbonaceous shales, for the most part arenaceous, and more than 100 feet thick. So combustible are these shales that in a part of the mine where they were accidentally fired they have smouldered on for more than eighteen months and are still alight.

Time did not admit of a search for plant-remains; but a diligent search, especially in the finer and more argillaceous beds, would be almost certain of success. Thin seams of very impure coal full of pyrites occur in the black shales; and here and there a long flattened piece of pure coal is found, probably the stem of some plant altered to coal and flattened by compression.

At De Beer's mine, on the north side, a somewhat different section is laid bare. First there is, from the surface down, about 50 feet of dolerite, then about 12 feet of yellow thinly laminated shales; beneath these are the black carbonaceous shales, corresponding with those in Kimberley mine, and also containing thin seams, up to 1 inch in thickness, of impure coal.

The precise depth of these carbonaceous shales has yet to be determined; but that they extend horizontally over the whole country at no great depth below the surface there is no reason to doubt; for wherever wells have been sunk in the neighbourhood of Kimberley, De Beer's, Du Toit's Pan, or Bultfontein, these black shales have been encountered at depths varying from 40 to 60 feet from the surface. These shales are to be traced cropping out on the banks of the Modder river †, some forty miles from Kimberley, and

* [See E. J. Dunn's previous papers, Quart. Journ. Geol. Soc. vol. xxx. p. 54; and vol. xxxiii. p. 879.]

† [Quart. Journ. Geol. Soc. vol. xxx. p. 582.]

again on the Riet river, still further away. How much further they extend can only be determined by boring; for the level nature of the country prevents one from obtaining any knowledge of the beds 100 feet below the general level.

That the old mines are volcanic "pipes," and that they have burst through these carbonaceous shales is evident. Is it not reasonable to infer that the carbon, indispensable in one form or another to the formation of diamond, was supplied by these shales?

It is well known that at and near the surface, or while the workings in the "pipes" were bounded by grey shale, the mines were not so productive as at lower depths; when the zone of black shales was reached the diamonds were more plentiful and also of better quality.

At Kimberley the improved yield as depth was attained was well recognized; and at Bultfontein mine so notably is this the case that, though the surface-ground scarcely paid for working, the yield at a depth of from 60 to 80 feet is most satisfactory. Jagersfontein, in the Free State, again, is an instance of a mine poor at the surface, but very profitable to work lower down.

So far as experience can be drawn on as a guide, it appears that the yields of diamonds in these "pipes" are greatest when mining is carried on in the portions of the "pipes" surrounded by carbonaceous shales, rendering it probable that these shales supplied the element necessary to the formation of diamond.

A practical question of serious importance as regards the diamond-mining industry here suggests itself: if the black shales supplied the carbon of which the diamonds are formed, it is to be expected that some diamonds would be found higher in the "pipes" than the black shale; for the tendency of the molten rock would be to rise, and this would also be the case with carbon in the state of vapour; but is it probable that diamonds will be met with *below* these shales?

Already in three separate localities shafts sunk at the edge of Kimberley mine have, at a depth of 300 feet, struck remarkable intrusive rocks—amygdaloids, breccias, &c. that differ essentially from any thing found penetrating the surface-shales. Whether these are older intrusive rocks on which the shales were laid down, or whether they are later than the shales and penetrate them is not yet decided.

That the "pipes" will continue down for a vast depth there can be no doubt; but if beneath the black shales the "pipes" have traversed rocks devoid of carbon, are diamonds still to be expected in them?

Koffyfontein mine, on the road between Kimberley and Jagersfontein mines, has so far not proved rich at the surface. Many other undoubted "pipes" have been opened and prospected near Kimberley; but subsequently they have been abandoned as unremunerative, although some diamonds were obtained. It is very probable that by deeper sinking in these localities richer yields would be found, as the black shales are almost certainly below.

Should it prove to be the case that these carbonaceous shales provided the carbon for the diamonds, the conclusion is forced on us that the original source of the diamond is the atmosphere; for the plants absorbed carbonic acid gas from the air, and in course of time were entombed, and thus provided a store of carbonaceous matter in the shales. Later on these shales were shattered and engulfed in the molten rock. The carbon was then liberated in the state of vapour by the intense heat; but, being under great pressure in the "pipes," instead of escaping, it crystallized out as sparkling diamonds.

The disclosure of such extensive deposits of carbonaceous shale has other bearings quite as important as on the formation of diamonds. Hitherto no such deposits were known to exist in the Karroo beds or *Dicynodon* series of rocks that cover such an immense area in Cape Colony and the Free State. Vast plains broken by hills, either isolated in groups or in long ranges, characterize the country occupied by these rocks; the river-beds are generally shallow; and thus it happens that until the southern limit of the Karroo beds is reached, which is 200 miles direct from Kimberley, no section, even to a moderate depth below the general level is obtainable.

At their southern termination these horizontal beds abruptly cease, exposing their edges through a thickness of more than 3000 feet, and form the Nieuwveldt, Camdeboo, and Winterberg ranges of mountains.

No seam of coal has been found along these well-exposed edges, although well searched for. Very insignificant thin seams of black shale do exist, also occasional plant-remains in the form of *Glossopteris* and *Equisetum*, but no such shales as at the diamond-fields. The remarkably pure anthracite found vertically intersecting the rocks (Karoo beds) at Buffel's Kloof, Camdeboo* has been proved by boring to be the result of distillation, perhaps ensuing from the action of intrusive rocks on the vegetable remains included in the shales. At the above locality a large dyke underlies the outcrop of anthracite, though at the surface it is several hundred yards distant.

The trough of the great basin occupied by the Karroo† beds lies south of the Orange river, and about east and west. Is there not a possibility that these carbonaceous shales cropping out near the northern limit of the Karroo beds may develop into true coal-seams further south, or nearer the centre of the basin? A couple of bore-holes would settle the point; and the pressing need for fuel at the diamond-fields will ensure the trial being made.

In previous notes some dyke-like masses at De Beer's mine were described as noticeable near the surface; now that the workings have reached a depth of over 100 feet these dykes are less equivocal, as the rock forming them appears in almost its original condition, and not decomposed as at the surface; it is of dark bluish-

* [See E. J. Dunn's Report to the Colonial Parliament, 1879.]

† [This name, as used by Mr. Dunn, excludes the Uppermost Karroo or Stormberg beds.]

grey colour and somewhat crystalline texture. It appears to differ from the general mass filling the "pipe" only in being fine-grained and less liable to decompose. These dykes are from 2 to 3 feet thick; they cut through the gabbro filling the "pipe," and the carbonaceous shales, grey shales, and dolerite that form the sides of the "pipe." No similar dykes were observed in any of the other mines.

At Bultfontein mine the shales on the east side are much disturbed, and are tilted in places at an angle of 60° away from the "pipe." There are numerous blocks and small pieces of dolerite in this mine that have been so rounded by attrition against one another, probably caused by the heaving of the mass when in a molten state, that they resemble boulders and pebbles. These stones are not so noticeable in any of the other mines as they are at Bultfontein.

As an instance of the value of the ground filling these "pipes," the following (on good authority) is of interest:—

At Du Toit's Pan 7000 loads, 16 cubic feet each, yielded, on an average, diamonds to the value of £2 12*s*. per load.

Discussion

Prof. Ramsay said the facts mentioned were remarkable; and it was extremely difficult to say what the circumstances were under which diamonds were developed.

Mr. J. Evans said that the author had in this paper gone further than he had done in his previous communication. Last year small diamonds had been shown at the Royal Society made, it was said, artificially. It would be an experiment worth while for Mr. Hannay to repeat, in the form of heating together pieces of carbonaceous shale and of fusible igneous rock.

Prof. Seeley said the view of the author was a plausible one. He himself had suggested that carbonic acid might have been carried down by water, and then decomposed by the heat of the volcanos, so that the carbon, when liberated, might become crystallized. The general principle of the author's theory might be true, though, perhaps, not the precise application of it.

41. Silurian Uniserial Stomatoporæ *and* Ascodictya. By George Robert Vine, Esq. (Communicated by Professor P. Martin Duncan, F.R.S., F.G.S.) (Read June 22, 1881.)

The genus *Alecto* was founded by Lamouroux in 1821 for a group of adherent Polyzoa. In 1814 Leach had used the word *Alecto* for a genus of Echinoderms; and Mr. Hincks says that it is still employed in connexion with the Crinoidea. On this account its further use for species of Polyzoa is objectionable. In 1825 Prof. Bronn used the word *Stomatopora*, and in 1826 Goldfuss used *Aulopora*, as names for individuals of the same genus as that founded by Lamouroux. For uniserial species d'Orbigny employed Prof. Bronn's name; but Blainville, Johnston, Milne-Edwards, Busk, and Defrance used the original word "*Alecto*" for species described by them in their various writings.

The generic characters of *Stomatopora* have been given by various authors; and additions have been made from time to time. The rather full description given by Goldfuss* of *Aulopora dichotoma*, together with figures of the species, renders identification comparatively easy. But somehow there has been a confusion in later identifications, and the *Aulopora intermedia* † type of Münster has been mixed up with Goldfuss's type. Both of these are present in the Jurassic formation; and it is, I will admit, rather a difficult matter to say where the one ends and the other begins. If, however, authors would distinguish between the two types, we should be able to get at the true range of the species, because each has an individual facies of its own. Hall, in describing the species found in the Trenton Limestone of America ‡ (Trenton Falls, Oneida county), makes this distinction:—In *Alecto inflata* we have the tubes short and individually separate; whilst in *Aulopora arachnoidea* the tubes are not distinct or separated from the general consistence of the branch. Jules Haime, in his descriptions of the fossil Bryozoa of the Jurassic rocks, places the whole of his species under one genus; and I prefer this method rather than object to it. Thus, *Stomatopora antiqua* from the Inferior Lias of Valière, *S. Terquemi* from the Inferior Oolite, and *S. Bouchardi* from the Oxford Clay are of the *Aulopora intermedia* type; and this holds good with species found in our own country. *Stomatopora dichotoma*, *S. dichotomoides*, D'Orb., and *S. Waltoni* are of the same type as that given by Goldfuss as *Aulopora dichotoma*. In *S. Desondoni*, Haime, from the Inferior Oolite of Longwy, we have a passage-form between *Aulopora intermedia* and the genus *Proboscina*, and then species of *Proboscina* passing by gradations, with a tendency on the one hand to the *Idmoneæ*, and on the other to the larger

* Petrefacta Germaniæ, p. 218, pl. 65. f. 2.
† Ibid. p. 218, pl. 65. f. 1.
‡ Palæontology of New York, vol. i. p. 77.

Stomatoporæ. There are in all the species and genera named individual characters, if isolated, that would indicate affinities in the whole group; and Mr. Hincks is wise in grouping all these genera under one family name, that of the Tubuliporidæ.

Prof. H. Alleyne Nicholson, in working out material submitted to him for examination by Mr. U. P. James, of Cincinnati, and also material collected by himself, saw fit to rename the species of Hall *Hippothoa inflata,* and, according to his description, shifted the species from the suborder Cyclostomata to that of the Cheilostomata of Busk. I could not from the first agree with the Professor; but I was unable to dispute the point raised by him otherwise than by the mere expression of opinion; for up to the present time no record has been given of species of *Stomatopora* found in our own Palæozoic rocks. I am now able to carry back the true uniserial *Stomatoporæ* to the Lower Wenlock Shales of Shropshire.

It may be as well to say a few words about the material used by me for this and other papers (to follow) on Silurian Polyzoa. It is now pretty generally known that, for the purpose of assisting Mr. Thomas Davidson, F.R.S., in his labours on the Silurian Brachiopoda, Mr. George Maw, F.L.S. and F.G.S., of Benthall Hall, Shropshire*, has had washed and carefully picked, for Brachiopoda, about 18 tons of Wenlock shales. The *débris* of these washings were after this laid aside for the use of other specialists. Some time since I applied to Mr. Davidson, and afterwards to Mr. Maw (Mr. Davidson supporting my request), for some of this refuse, for the purpose of working out stratigraphically the Polyzoa and smaller Actinozoa. My request being granted, Mr. Maw sent me on the 19th of March over two hundredweight of the *débris* for this purpose. I intend to use the whole of this material honestly; for I feel convinced that it can be only by labours such as these that a true idea of the abundance of the Polyzoal life of former epochs can be obtained; and, though picking out fragments from such a mass, by the aid of a hand-glass, may be both painful and tedious, I shall prefer to work on different groups, as material accumulates, rather than delay writing till the whole has been picked. I have already gone over about thirty pounds of the *débris* from the eleven localities and horizons; and it may be interesting, as showing the difference between the shales of the Carboniferous and the shales of the Wenlock series, when I say that a single pound of unwashed Hairmyres clay would yield me in the washing more individual specimens than I have been able to get from the thirty pounds of the Wenlock *débris.* In the Carboniferous the fragmentary organisms are tolerably well preserved and perfect; in the other the Polyzoal remains seem to have been much waterworn, but, with the exception of one locality, not sufficiently injured to prevent identification.

We are indebted to Prof. Hall for the first indication of the existence of uniserial *Stomatoporæ* in Silurian rocks. It is quite

* See Geological Magazine, Jan., March, &c. 1881.

possible that Lonsdale and other workers on the Silurian organisms may have had a previous knowledge of the fact of their existence in these rocks; but no detailed account was furnished. For the working-out of these and other forms of *Stomatopora* we are equally indebted to Prof. Nicholson, M.D., F.G.S., &c.

Silurian Stomatoporæ.

1. Stomatopora inflata.

Alecto inflata, Hall, Palæont. of New York, vol. i. p. 77, pl. xxvi. figs. 7*a*, *b*, = *Hippothoa inflata*, Nicholson, Ann. & Mag. Nat. Hist. Feb. 1875, pl. xi. figs. 1, 1*a*.

"*Zoarium** attached, arachnoid; *zoœcia* short, much expanded above, contracting at the aperture and narrowing rapidly below: orifice large, opening obliquely upwards."

This is Hall's description of his species. Nicholson says that the branches of his specimens are linear, and the "cells uniserial and pyriform, each springing by a contracted base directly from the cell below; about four cells in the space of one line." There is nothing, however, in his description that would ally the species with the *Hippothoæ*; but in working out my own Upper-Silurian types I have given prominence to every feature that had any tendency to a Hippothooid character.

The geological position of Hall's species is the Trenton Limestone. Nicholson's specimens are from the Hudson-River Formation, Cincinnati Group.

2. Stomatopora dissimilis, mihi. Figs. 1–8 (p. 616).

Zoarium adnate, branching, generally attached to stems of Crinoidea, very rarely to broken shells; branches linear, sometimes wavy and anastomosing. *Zoœcia* invariably uniserial, and, in the best preserved, very finely ribbed transversely; the oral extremity slightly raised; orifice circular or subcircular. *Oœcial* cells rather ventricose and strongly ribbed (?). Each normal zoœcium about half a line; average about 6 to $3\frac{1}{2}$ lines.

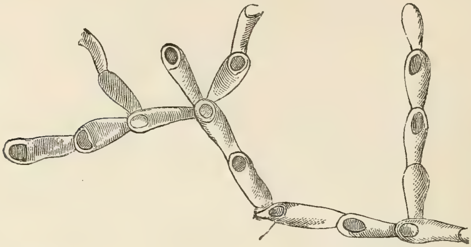
Loc. Upper Silurian: "Buildwass beds," Harley, near Wenlock, rather rare; also base of Wenlock shale, Buildwass Bridge, Shropshire, rather common.

I have not found any specimens of this species in any other of the eleven localities which I have searched for Polyzoa. In searching the material from these two localities, I found it to my interest to examine on both sides every fragment of shell and Crinoid that came under my glass: the consequence of this is that I have specimens, more or less perfect, of about fifty colonies. The drawings are made from three of these, because they afforded me better facies than the others. What I have given are characteristic of the whole.

* To present a uniformity in the descriptions, I change the exact words of authors to those in present use: thus, Hall's word "Coral" is changed to Zoarium, "Polyzoary" of authors to the same.

Figs. 1–8.—Stomatopora dissimilis, *Vine, from the Buildwass beds, Upper Silurian, Shropshire.*

Fig. 1.



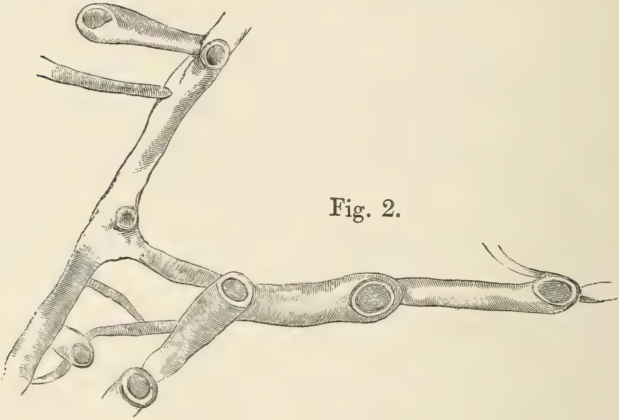
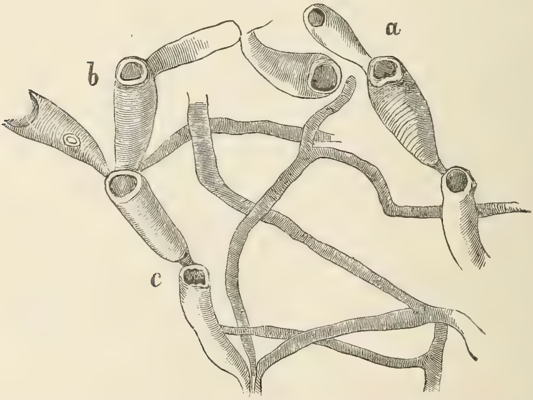


Fig. 2.

Fig. 3.



1. Colony adherent to Crinoid stem.
2. ,, ,, ,, ,,
3. ,, ,, ,, ,,

} Each of these colonies has been drawn with the Camera lucida, from three separate specimens on Crinoid stems, the habit of each colonial growth be ing somewhat dissimilar in character.

Fig. 4.

Fig. 5.

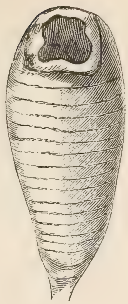


Fig. 6.

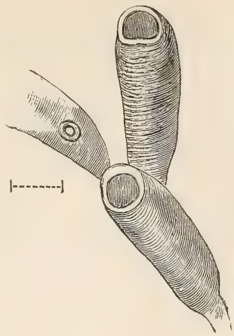


Fig. 7.

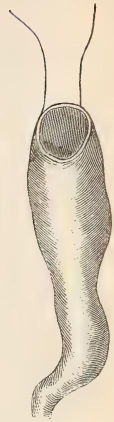
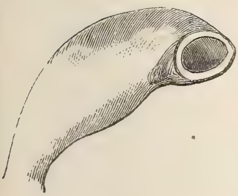


Fig. 8.



4. Profile of two cells from No. 3 colony, only lower down on specimen.
5. Magnified cell on same colony (fig. 3, *a*).
6. Three cells from same colony (fig. 3, *b*).
7. Cell from same colony, with caudate elongation (fig. 3, *c*).
8. Cell from another colony. The stoloniferous processes on specimen No. 3 do not belong to the Polyzoal colony, but to *Ascodictyon.* Upper Silurian, Buildwass beds, base of Wenlock shale, Shropshire.

The habit of the colonial growth, as given in fig. 1, is similar to that of *Aulopora dichotoma,* Goldf. Generally speaking, about every second cell gives origin to a fresh one; and this is the beginning of a new branch. I cannot, however, give this as a character, on account of its variableness. The origin of fresh colonies of this beautiful species is a most interesting study. Without speaking positively on this point, I have in one small fragment probable evidence that clusters of cells are developed from one of the "rosettes" of *Ascodictyon stellatum,* Nich. and Ether.* Around this cluster primary cells of various colonies are disposed; some colonies have a linear arrangement of from three to five cells; the primary cells are also disposed singly on different parts of the fragment of broken shell; a larger mass of cells clustered in one spot give origin to several linear branches of what I am disposed to believe are new colonies. It may, however, be possible to explain this feature by stating that one rosette gives origin to several linear branches, and the whole clustered together would be the parental nucleus of one colony variously disposed. There is sufficient evidence to show that some colonies at least sprang from an independent primary cell.

Amongst living *Stomatoporæ* a most remarkable feature is shown in the figures of *S. fasciculata,* Hincks, pl. lix. figs. 4, 5†. In his descriptive text (p. 441) Mr. Hincks separates this from all other

* Ann. & Mag. Nat. Hist. June 1877.
† Hincks, Brit. Marine Polyzoa, vol. ii.; text, vol. i.

known species, and places it in a division by itself (C. *Colony clustered*). In the figure there are several peculiar clusters of cells, including from two to five or seven cells. There are no stoloniferous processes. In comparing the feature given here by Hincks with that of Nicholson's figure of *Ascodictyon stellatum*, and both of these with my own specimen, I cannot arrive at any other conclusion than that some of the *Ascodictya* of the Palæozoic rocks are in some way homologous with the cluster found upon Hincks's unique and solitary specimen of *S. fasciculata.*

The profile of two cells, fig. 4, shows the true Stomatoporous development. There are some cells in fig. 3 that are of a most peculiar character. They differ in a few particulars from other cells; and these I have ventured to suggest may be the oœcia of the colonies. I may, or I may not, be right in my conjecture on this point. Unless these be oœcia, I have not been able to trace in any other cells the least indication of ovarian chambers. 5 is a good illustrative example of the cell referred to. Other points of structure are alluded to in the description of the figures.

In the Annals and Magazine of Nat. History for June 1877, Messrs. Nicholson and Etheridge, Jun., described and figured a most peculiar and "anomalous genus of Palæozoic fossils." The name given to the group was *Ascodictyon*; and several species were described as found in Devonian and Carboniferous rocks. The systematic position and affinities of the fossils were not established by the authors when the paper was written. From material in my own cabinet I ventured to suggest, in a letter to Prof. Nicholson, what, judging from the Carboniferous fossils, I believed to be the probable affinities. I have now discovered in the Silurian shales of Shropshire several specimens of the species given by Nicholson; and so carefully are the characters of the Devonian fossils made out, that I can trace in the Silurian specimens a most remarkable resemblance. In the stellate rosette and stoloniferous processes there are differences so slight that I was inclined to place my own fossils under the same generic and specific names, distinguishing one only with a varietal term *.

3. Ascodictyon stellatum, Nich. & Eth., Jun.

I have only two specimens of this type. There are a few differences, which it may be well to indicate by giving it the varietal name, *siluriense*, mihi.

Colony composed of calcareous clusters of ovoid cells, having a somewhat stellate character; each cluster containing from four to seven cells, which are connected together by creeping filamentous cords, some of which anastomose at intervals.

Loc. Buildwass beds, near base of Wenlock Shale, Shropshire.

* Since this was written, I have been able to work out fuller details of this most remarkable group; and I may add that Professor Nicholson has furnished me with specimens of his so-called *Hippothoa inflata*, particulars of which will be given in a future paper on the Polyzoa of the Wenlock Shales.

4. Ascodictyon radians?, Nich. & Ether. (Provisional placement.)

I have several colonies of this beautiful type apparently similar to those found in the Carboniferous rocks of Scotland. The colonies are not so prolific, however, in the Silurian as they are represented to be in the East Kilbride district. In the Silurian the clusters rarely exceed two or three; in many cases there is only one stellate group of "elongated vesicles." For the present I merely record their discovery, reserving more detailed description for some future time when my material is better worked.

Loc. Buildwass beds, near base of Wenlock Shale, Shropshire.

Hab. On stems of Crinoidea and fragments of shell.

Without committing myself to any systematic classification (other than that suggested in the text) of these peculiar fossils, I think it would be unwise and ungenerous on my part to conclude this paper without speaking most approvingly of the labours of Prof. Nicholson and Mr. Robert Etheridge, Jun., in the same direction as my own. Prof. Nicholson remarks, in the paper on *Ascodictyon**, that this "genus, so far as our present knowledge goes, is confined to the Devonian and Carboniferous periods." I am now able to extend its range.

Ascodictyon, Nich. & Ether. Jun.

Upper Silurian......	*A. stellatum,*	var. *siluriense,* mihi.		....	Shropshire.
Middle Devonian...	*A. stellatum,*	Nich. & Eth.		....	Hamilton, Ontario.
,, ,, ...	*A. fusiforme,*	,,	,,	....	,, ,,
Upper Silurian......	*A. radians?,*	,,	,,	my own cabinet..	Shropshire.
Carb. Limestone ...	*A. radians,*	,,	,,	,, ,,	Scotland.
,, ,,	*A. stellatum*	,,	,,	,, ,,	,,

Stomatopora, Bronn, uniserial species.

Lower Silurian......	*S. inflata,* Hall	Trenton Limestone, America.
,, ,, ...	*S. inflata,* (*Hippothoa inflata,* Nich.)	Hudson-River Formation.
Upper Silurian......	*S. dissimilis,* Vine; my own cabinet	Buildwass beds, Shropshire.
Permian	*S. Voigtiana,* King.	Humbleton, Yorkshire.

Discussion.

The President stated that very important results were being obtained from these washings of Mr. Maw's of Upper Silurian rock. Some of those obtained by Mr. Davidson were of the highest value. *Aulopora* had been made a receptacle for very various forms.

Prof. Duncan said that the value of Mr. Vine's researches was very great. The numbers of Polyzoa produced were very great; and some of the *Heteroporæ* were singularly recent in aspect.

* Ann. & Mag. Nat. Hist. June 1877.

42. *The* Reptile Fauna *of the* Gosau formation *preserved in the* Geological Museum *of the* University *of* Vienna. By Prof. H. G. Seeley, F.R.S., F.G.S., &c., Professor of Geography in King's College, London. *With a* Note *on the* Geological Horizon *of the* Fossils *at* Neue Welt, *west of* Wiener Neustadt, by Edw. Suess, Ph.D., F.M.G.S., &c., Professor of Geology in the University of Vienna, &c. (Read June 8, 1881.)

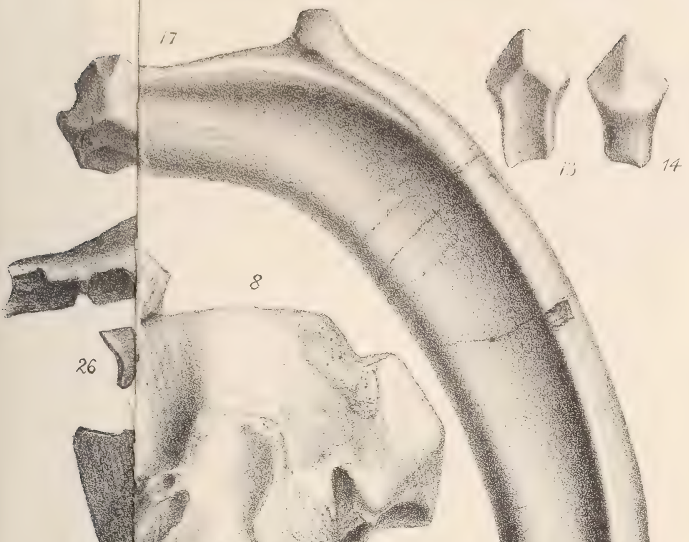
[Plates XXVII.–XXXI.]

Contents.

Introduction.

Historical Review.

The Gosau formation, nearly corresponding in age to the Upper Greensand of this country, is represented at Neue Welt, near Wiener Neustadt, by freshwater deposits full of such freshwater shells as *Melania* and *Unio*, and land-plants such as *Banksia* and *Pecopteris*. The formation and its fauna have been described by Profs. Suess, Zittel, and many others; but, although the late Dr. Stoliczka detected a tooth imbedded in the coal of the formation, no important knowledge was obtained of the vertebrate fauna of the Gosau beds until Prof. Suess



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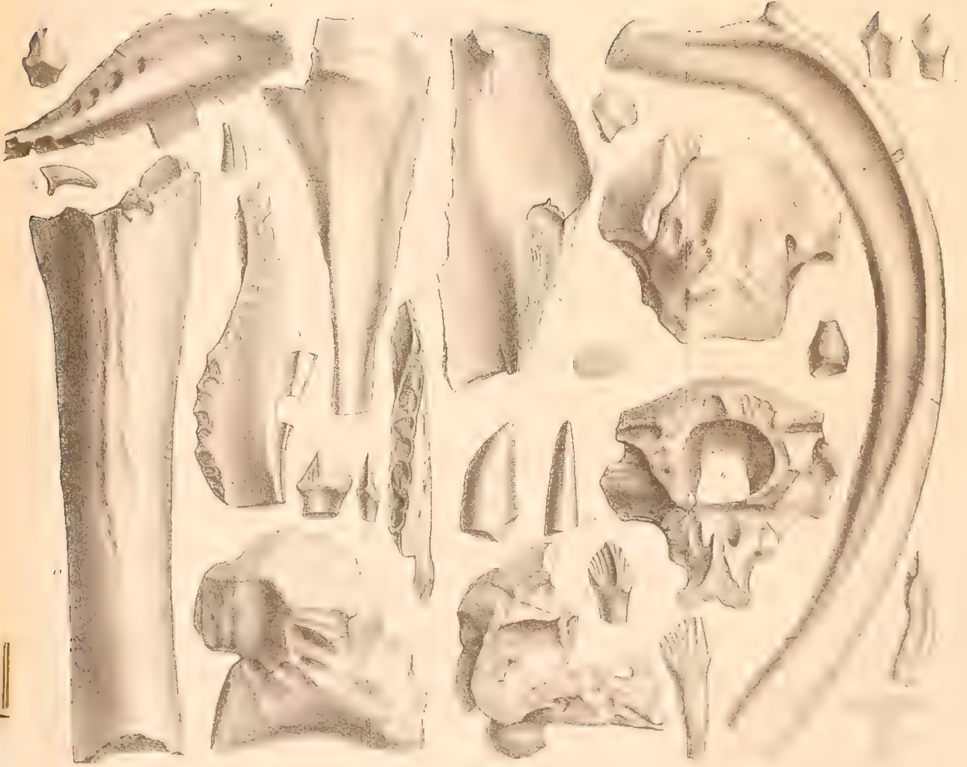

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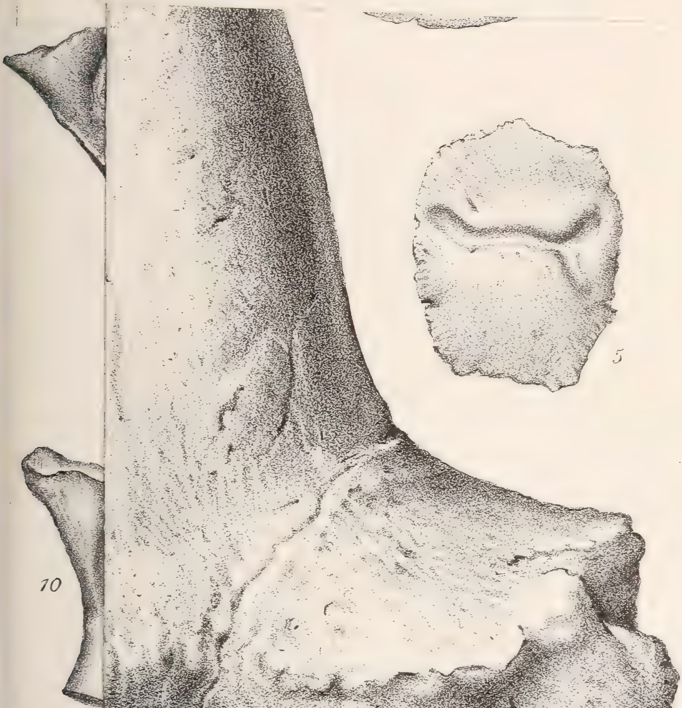
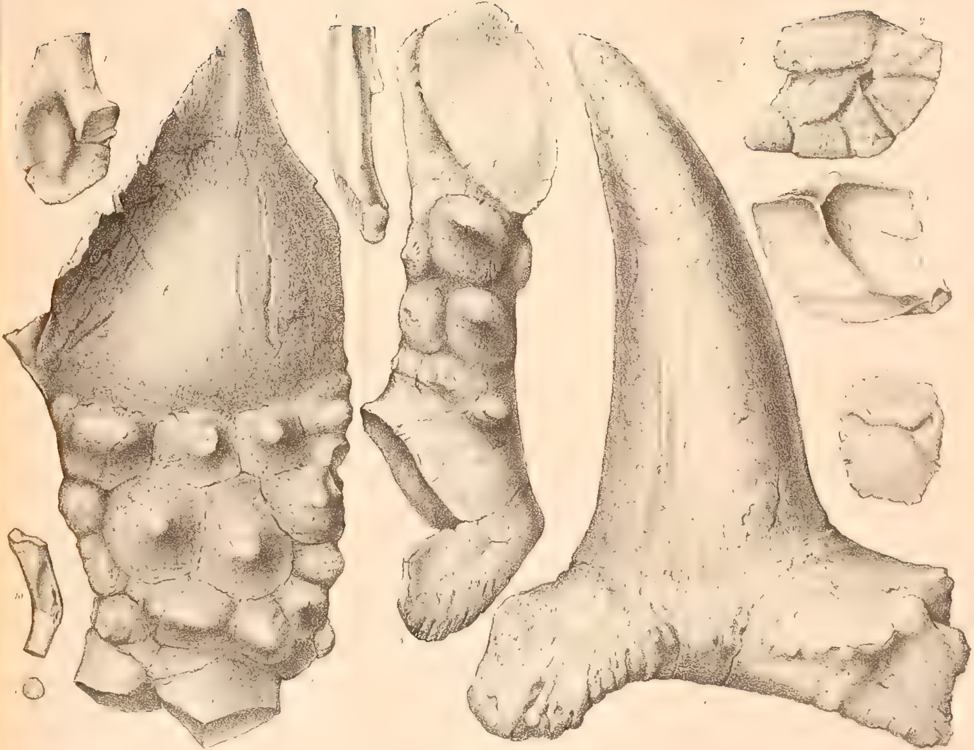


Hanhart imp.



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REPTILIAN RE

was so fortunate as to obtain the assistance of Bergverwalter Pawlowitsch in conducting excavations. These were carried on with admirable skill; timber drift-ways were driven into the rocks, with the result that they penetrated into a perfect cemetery of the remains of Cretaceous reptiles. The remarkable collection thus obtained was intrusted for description to Dr. Emanuel Bünzel, whose memoir upon it was published in 1871 in the 'Transactions of the Imperial-Royal Geological Institution.' Subsequently more specimens were discovered; and in Easter 1879 my honoured friend, Prof. Suess, invited me to visit Vienna to examine these specimens, with the object of making them available for the advancement of knowledge by publication. With the assistance of the Royal Society I gladly undertook this work, and spent a month in Vienna studying the thousands of fragments which had been obtained. The great mass of these, mere comminuted bones, proved of but little value; or, rather, the time that I could give to their study enabled me to piece together but few specimens that were likely to prove interesting. There were, however, other important remains, which Prof. Suess had already reconstructed and pieced together with great patience and perseverance, that had produced many indications of lost animal forms out of a chaos of débris. I soon found that Bünzel's views and my own presented certain differences. His memoir, which extends to eighteen quarto pages, and is illustrated by eight plates, describes the following species—*Crocodilus carcharidens*, *Iguanodon Suessii*, *Struthiosaurus austriacus*, and *Danubiosaurus anceps*. Other remains are referred to the genera *Hylæosaurus*, *Scelidosaurus*, and *Lacerta*; while certain specimens are classed as "Crocodili ambigui," Chelonians, and indeterminate remains. All the specimens which he described are figured; but the artist has so imperfectly appreciated the details of character of the fossils represented in Bünzel's plates, that it is impossible to form from them a just opinion of these fossil reptiles. After examining the specimens, I have come to the conclusion that some of Bünzel's identifications may be modified. I am unable to recognize *Scelidosaurus*, of which Bünzel figures a claw-phalange, tail-vertebræ, and dermal armour. *Hylæosaurus* is another genus doubtfully cited, resting upon a single scute, which it may be well to discard. *Lacerta* is a genus that certainly cannot be recognized, although the author refers to it parietal and postfrontal bones, the articular element of the lower jaw, and the right side of the lower jaw, vertebræ, fragments of ribs, humerus, radius, and femora. But the genus *Lacerta* could here only be used in the sense of animals of the Lizard group.

For reasons that will be adduced, the *Crocodilus carcharidens*, founded upon a fragment of the lower jaw, cannot be referred to the genus *Crocodilus*; while the *Danubiosaurus anceps* was founded in error, and the remains, instead of being lacertilian, belong to other orders and other parts of the skeleton than those identified. *Struthiosaurus* being founded on a single specimen, remains an interesting type; but I feel constrained to refer the *Iguanodon Suessii* to a distinct genus.

The vertebræ, plate i. figs. 24–26, regarded as crocodilian, pertain to a small Dinosaur; figure 27 in the same plate, regarded as the dorsal rib of a Crocodile, I interpret as the cervical rib of a Dinosaur. The vertebræ, regarded as crocodilian, which are figured in pl. ii. give evidence of a second and larger species of Dinosaur, and exemplify its cervical, caudal, and dorsal vertebræ.

On plate iii. fig. 1, the specimen regarded as the right side of a hinder dorsal rib of a Teleosaur I regard as the shaft of the femur of a new Dinosaurian genus. Figures 2–4, described as a crocodilian femur, is the femur of the larger Dinosaur. Figures 5, 6, called fragment of lower jaw of a Lizard, is certainly neither a fragment of jaw nor a Lizard-bone, but the proximal end of a large rib of a Dinosaur. Figures 12, 13, called the upper half of a crocodilian humerus, I regard as the proximal part of a Dinosaurian fibula.

In plate iv. figs. 1, 2, classed as dermal bones of a Crocodile, I refer to one of the large new Dinosaurs. Figure 3, described as the right ilium of *Iguanodon Mantelli*, is certainly a coracoid of a large Dinosaur. The tail-vertebræ on the same plate, referred to *Scelidosaurus*, are caudals of the same Dinosaurian genus already referred to. The figures 11, 12, called phalange of crocodilian, is a Dinosaurian metacarpal or metatarsal; and the claw-phalange (figs. 4, 5), referred to *Scelidosaurus*, probably belongs to the same animal.

The figures of the remarkable skull of *Struthiosaurus*, represented on plate v., are all unsatisfactory, since they give but a vague idea of its structure. Figures 7–9, described as the rib of a lacertilian (*Danubiosaurus anceps*), represent the scapula of the larger Dinosaur. Figure 10, termed claw-phalange of *Danubiosaurus*, was shown by Prof. Suess to be a piece of Dinosaurian armour, since he fitted it to a remarkable horn-like scute of the larger new Dinosaur.

On plate vi. figs. 1–3, is represented another example of the large Dinosaurian scapula, there interpreted as the rib of *Danubiosaurus anceps*. Figures 4, 5 are said to represent the left ilium of this imaginary animal; but they are really the costal plate and blended rib of a large and remarkable new Chelonian type. Figures 8–10, termed bodies of vertebræ of Lizard, are vertebræ of the same species of Crocodile represented on plate i. Figures 6, 7, described as the articular part of the lower jaw of a Lizard, are really the articular end of the lower jaw of a Pterodactyle of the genus *Ornithocheirus*. I concur with the identification of fig. 11, as vertebra of a Lizard. The bone represented in figures 12, 13, termed dorsal rib of Lizard, is the fibula of a Crocodile. I am unable to recognize satisfactory Lizard-characters either in the humerus figured in this plate or in any of the bones represented in plate vii., while that represented in figs. 22 and 23, termed a rib, seems to me to be a femur of a new Dinosaurian genus. The Dinosaurian dermal armour in this plate, referred to *Scelidosaurus*, must be associated with the bones of one or the other of the large Dinosaurs already referred to.

All the specimens on plate viii. are Dinosaurian; and I should only differ from Dr. Bünzel in referring them, together with fig. 1 (which he terms tail-vertebræ of a crocodilian) to the principal Dinosaur.

Figures 2–4 are termed by the author vertebra of a fœtal Dinosaur; but I am not aware of any evidence which enables us to determine a matter of that kind, and I refer it to the same animal as the so-called Lizard-bones (pl. vi. figs. 14, 15, pl. vii. figs. 1–4).

Indicating these and some other differences of opinion from Prof. Suess, and arranging the material, old and new, into species according to my interpretation, I was invited to deal with the remains in such a manner as my conclusions made necessary. As the time available did not suffice for description of the whole collection, I was generously permitted to borrow, from the museum of the University of Vienna, the more important specimens, which required further study or to be figured. The results I now offer to the Geological Society. The subject confessedly presents great difficulties; and in the following memoir I have dealt with it to the best of my ability. As already stated, the bulk of Dinosaurian vertebræ, scutes, and limb-bones are referable to two species of the same genus differing in size and other characters. This genus is certainly new. But when we come to examine the corresponding skull-fragments, there are two species indicated (by lower jaws) which are both of about the same size. There is also the somewhat smaller Dinosaur indicated by Bünzel as *Iguanodon Suessi*; and there are teeth that appear to be referable to two other Dinosaurs, one resembling *Lœlaps* or *Megalosaurus*, and the other somewhat approaching the Scelidosaurian pattern. Hence there is great difficulty in referring the right jaws to the skeletons; and there is absolutely no evidence to show whether the hinder skull-fragment, called *Struthiosaurus austriacus*, belonged to one of these species, or is the only specimen of the animal hitherto discovered. I have therefore some doubt whether, in the endeavour to make the subject clear, a synonym or two may not be introduced, which can only be got rid of by the discovery of additional materials; and I put my views forward with some diffidence.

Of the new Chelonian indicated by costal plates which were separate from each other at the lateral margins, I find no other evidence except postfrontal bones indicating a skull covered with an elaborate pattern of minute scutes, and a strong but imperfect coracoid bone. Both these latter remains, however, are so typically Chelonian, although the skull-bones joined by squamose overlap instead of by suture, that I have no doubt of the propriety of including the costal plates in the Chelonian order, singular as is their form. This remarkable animal is associated with Emydian types which differ in no important respect from existing genera. The Pterodactyles are very imperfectly represented, and badly preserved, and require but brief notice. The Crocodilians, however, are more curious, partly from their remarkable resemblances to types previously known in the Greensand of New Jersey and Cambridge, and partly from displaying new characters in the vertebræ.

All the species hitherto discovered are peculiar to the deposit, and, with the exception of those temporally referred to *Crocodilus*, *Emys*, *Ornithocheirus*, and *Megalosaurus*, must, as it seems to me, be located in new genera. The most important new type is the Dinosaur *Cra-*

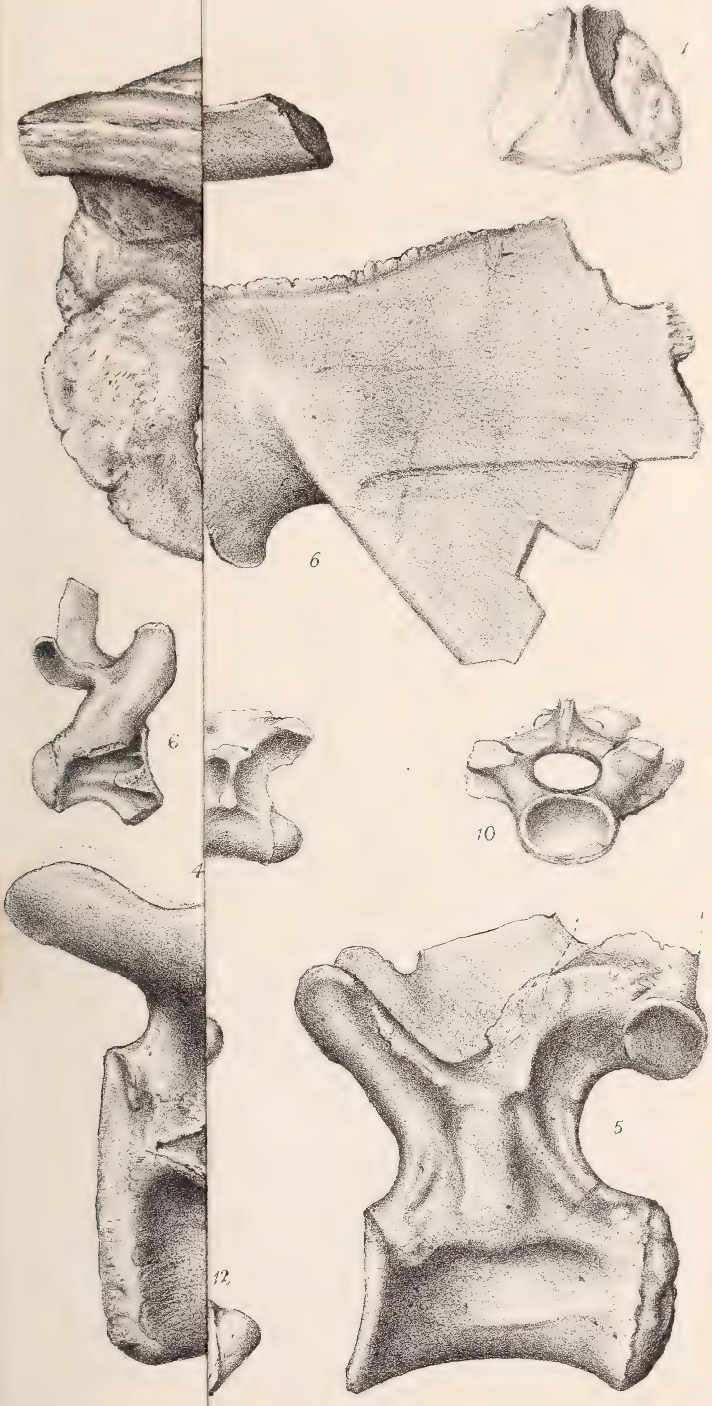
tæomus, represented by two species; the other Dinosaurian genera are *Doratodon*, *Rhadinosaurus*, *Mochlodon*, *Ornithomerus*, *Oligosaurus*, and *Hoplosaurus*.

Condition of the Specimens.

Almost all the bones are in fragmentary condition, and somewhat distorted by the effects of pressure. Being hollow, they have sometimes become greatly crushed; and were it not that both right and left bones are usually preserved, it would often be difficult to avoid being misled by appearances which result from conditions of fossilization. Unfortunately almost all the long bones have lost their articular extremities, and although in some instances this may perhaps be the result of fracture, yet in most cases it is certainly a consequence of decay of the bones before they were covered up in the deposit. I do not speculate as to whether the articular ends may have been eaten off by large carnivorous contemporaries; for there are no indications of tooth-marks or other evidences of animals which might thus have mutilated the specimens. No doubt to some this condition would be proof that the remains were derived from an older deposit; but since the Wealden and Cambridge Greensand and Stonesfield Slate all have a number of bones in a not dissimilar condition, it seems to me less hypothetical to find an explanation of their condition in prolonged maceration, coupled with the lithological and petrological modifications which the deposit has since undergone. There is, however, no record of natural association of any of the remains; yet, as they have mostly come from the same locality, it is probable that remains which agree in size and anatomical characters may, in most cases, with certainty be referred to the skeleton of the same individual, since duplicate parts of the skeleton are almost unknown in each species. There may perhaps be a certain amount of doubt as to the correct association of the remains which I have ventured to put together; but this is a doubt which the anatomist will best appreciate who can realize the nature of the studies which have led me to group the bones as here set forth.

Mochlodon Suessii (Bünzel). (Pl. XXVII. fig. 1.)
See Bünzel, *l. c.* p. 8, pl. iii. figs. 7–11.

One of the most beautifully preserved specimens is a right dentary bone of a small Dinosaur which at first sight exactly reproduces in miniature the characters of the *Iguanodon* of the Weald; but it differs in a character so remarkable that, had it occurred in a living animal, no hesitation would have been felt in relegating the jaw to a distinct genus. Anterior to the teeth, the symphysial extremity of every *Iguanodon*-jaw bends round so that the rami form a U-shaped curve; but this specimen is straight, and the anterior inward inflexion is scarcely appreciable, so that the snout was evidently sharply pointed, and therefore indicative of a new form of head. The fragment is little more than 7½ centimetres long, and the tooth-bearing part of the jaw 17 or 18 millimetres; the height at the



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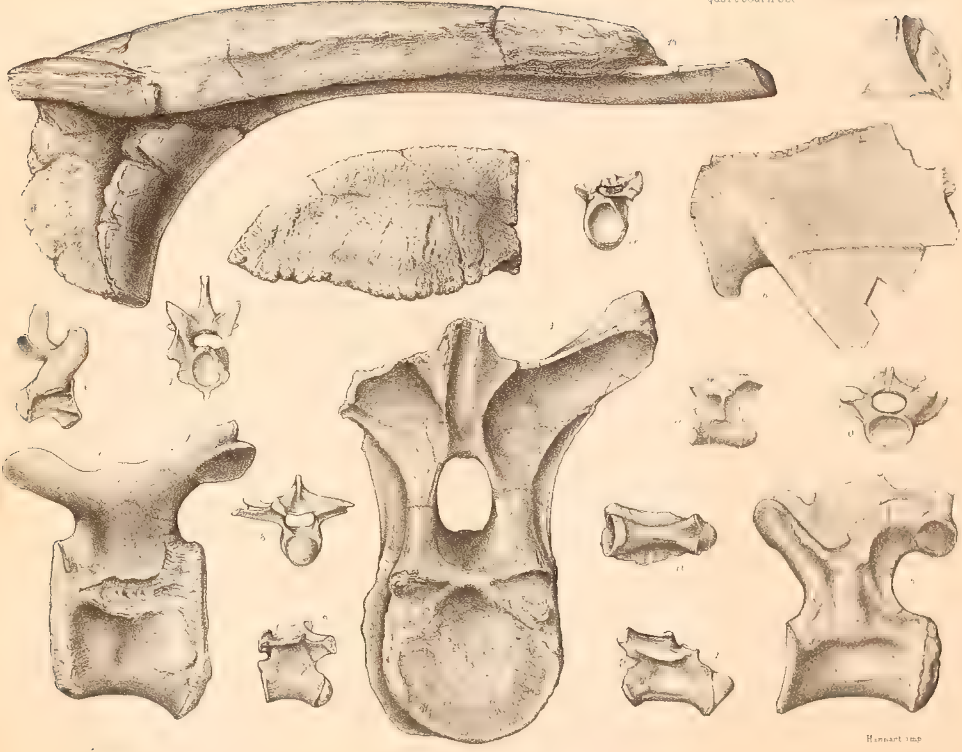

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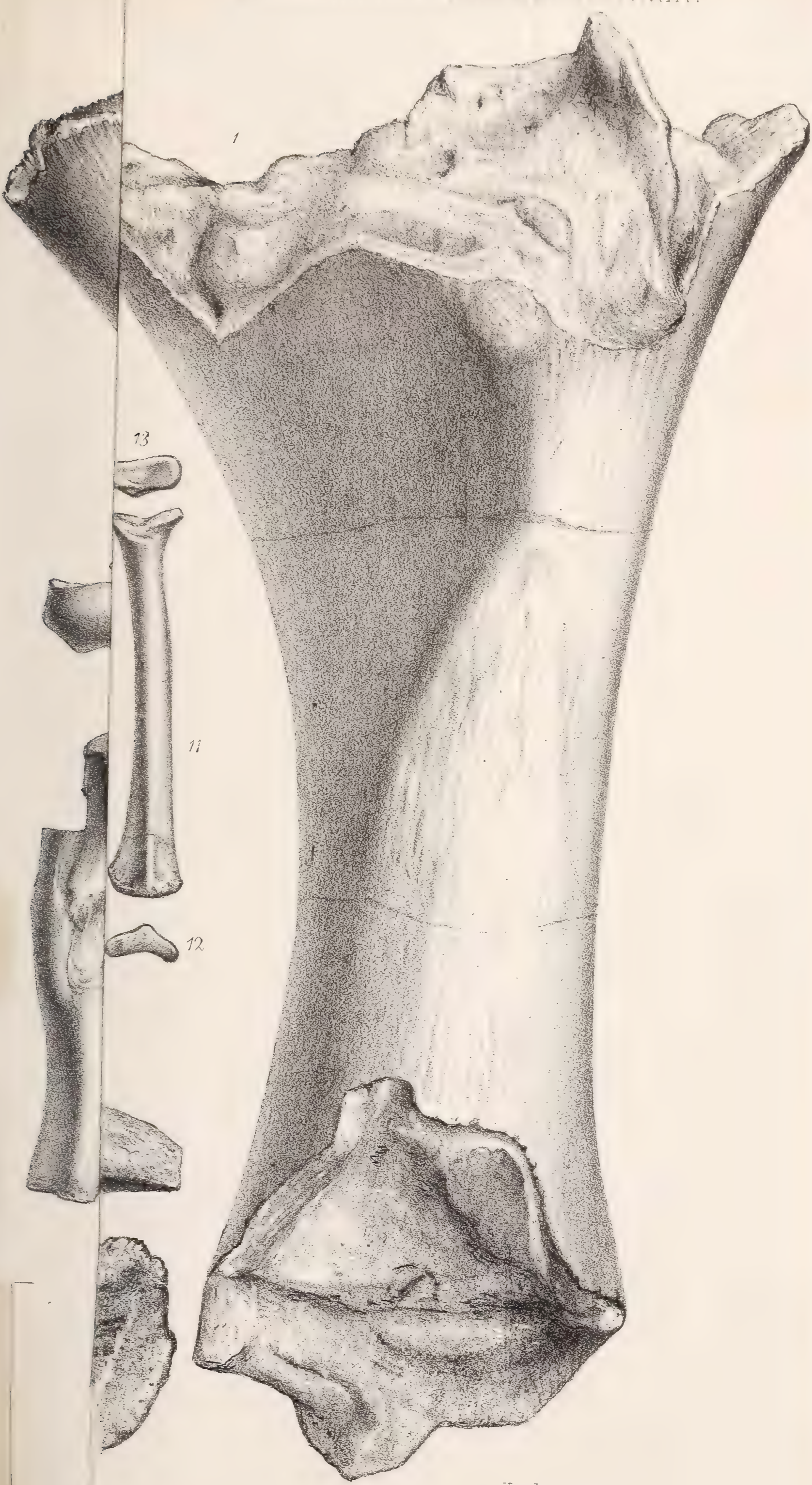
PTILIAN REMAINS



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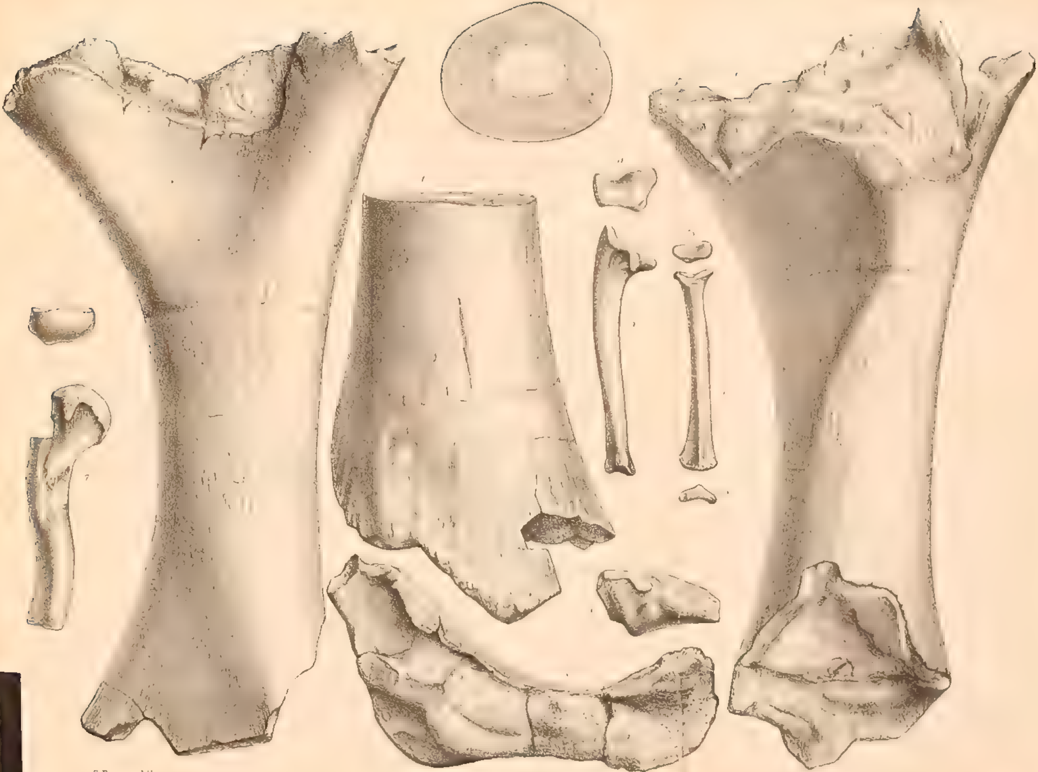

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GOSAU REPTILIAN REMAINS

posterior end to the top of the coronoid process, which is imperfectly preserved, is $3\frac{1}{2}$ centim. The external surface is smooth, rounded at the base, with a strong rounded ridge descending from the anterior margin of the coronoid process, and extending downward and forward along the jaw, dying away in front, and placed well above the middle of the side. Above this ridge the area of the jaw, extending inward to the alveoli, is flattened almost horizontally at the back; but the area becomes more oblique anteriorly, and undistinguishable as the ridge subsides. Along its upper and outer margin towards this ridge is a series of foramina which are elongated or ovate—four of them larger, and half-a-dozen smaller. The area below the ridge is flattened towards the posterior limit of the dentary bone; anteriorly it is flattened and pointed, being bevelled on the inferior border for its union with the other ramus, and on the superior border terminating in an oblique area, which is compressed from side to side and channelled by a somewhat deep groove. Whether this groove is merely vascular, or whether it may have contained a few premaxillary teeth, is a matter upon which I have no evidence. It is about 16 millim. long, wider and deeper behind than in front, and, as in the Wealden *Iguanodon*, has the inner border more elevated than the outer border. Below it are three or four vascular foramina. Both the inner and outer extremities of the jaw below are roughened, and indicate that the symphysis was loose, but held together by ligamentous union. As usual, the external outline of the bone, when viewed from above, is moderately convex, and its thickness from within outward continues to increase from before backward almost to the coronoid process. The inner side, which is slightly crushed, displays ten alveoli. Portions of five or more teeth are seen in the jaw; and there are impressions of others and empty sockets, indicating ten in all. The first tooth, which is unfortunately imperfect (wanting the extremity of the crown), is remarkable for the smoothness of its inner surface, which, however, is elevated into a very strong median ridge, leaving the sides slightly concave. The serrations visible on the anterior margin are slight, and do not extend down the tooth. It is not sufficiently elevated to have come into wear. All the succeeding sockets are empty, owing to the teeth having dropped out; but most of them show successional teeth coming up, which have not yet reached the level of the outer alveolar margin. The second and third teeth are broken away on their external part, and not recognizable. The fourth tooth, also wanting the extremity of the crown, still shows the same enormously developed median ridge; but external to it are, on each side, about half-a-dozen fine parallel ridges which have sulcations behind them of about their own width. The fifth tooth only just shows the top of its crown coming up low down in the alveolus. The sixth tooth is the best developed, was apparently the largest, and occurs near the thickest part of the jaw. Its pattern is like that of the last described; only the strong median ridge or keel is much sharper, and the lateral concavities deeper, in accordance with the width of the tooth. The lateral ridges run up and terminate in the sharp rounded lanceolate margin, and give it a crenulate appearance, which is due to their elevation. The median ridge terminates in a point, which is rounded and does not project beyond the tooth-margin. The tooth is slightly displaced, and leans backward towards the seventh socket. Low down in the seventh socket the crown of another tooth is seen. The eighth socket is empty. The ninth socket has lost the successional tooth, but displays the external impression, and shows it to have been marked with a median ridge and lateral finer ridges somewhat radiating upward. The tenth socket appears to have been small; it is imperfectly preserved, and there is no evidence as to its form or character; but a groove, which is smooth, is placed behind the last socket mentioned, and just in advance of the coronoid process. Hence these teeth appear to differ from those of *Iguanodon* in the persistent development of a powerful median ridge and in the striation of the external surface. Behind the alveolar border the bone becomes squamous and thin, having overlapped the surangular bone, though there is no trace of a separate coronoid element, from the suture entering into the coronoid process. An opercular bone, or its representative ossification, appears to have extended along the broad subdentary groove at the base of the bone margining its upper part, while the angular bone, if it were distinct from the surangular, would appear to have reached far forward along the base of this groove, and to have rested on a thin ledge of the dentary. The submaxillary groove, in its anterior third, becomes shallow, but persists to the symphysis. The region of the symphysis has no definite outline.

Two separate teeth, both such as may belong to this species, have been found. They are of small size, and may have belonged to this individual specimen. One belongs to the lower jaw, and might be the eighth tooth of the specimen described. The other is an upper-jaw tooth. The tooth from the lower jaw (Pl. XXVII. fig. 2) shows that the crown curves outward at a considerable angle to the fang; its outer margin is worn, showing that the teeth worked together with a scissors-like action, the lower-jaw teeth being, as usual, internal to those of the upper jaw. The external surface is marked with about half-a-dozen primary ridges; between these, in the middle of the tooth, are finer ridges; and across them run transverse lines of growth. There is no median external ridge. The internal aspect of the crown is essentially the same as in the specimens described in the jaw itself. The median ridge, however, is not prolonged down the fang; and hence there is a slight constriction at the base of this ridge; and the elevated lateral ridges sharply define this side of the crown from the smooth lateral areas.

The upper-jaw tooth (Pl. XXVII. figs. 3, 4) has the crown similarly curving inward from the fang. The fang is compressed from side to side, so as to give a subquadrate section. There is a slight constriction between the crown and the fang on the outer or cutting edge, but no constriction on the inner edge. The fang is imperfect at the base; but the total length of fang and crown, as preserved, is 18 millim. The worn surface (fig. 4), like that aspect of the tooth itself, is convex from side to side. The unworn part of the crown below is vertically striated; but the ribs are fainter than on the lower-jaw tooth. The inner surface of the crown is subquadrate, marked with eight vertical ridges, which are moderately elevated, stronger and wider apart on one side of the tooth than on the other. The height of the crown is about 8 millim., and its width about 7 millim. Its thickness at the base is about 4 millim.

Parietal bone of a small Dinosaur (*probably* Mochlodon).
(See Bünzel, pl. v. fig. 11, p. 14.)

The parietal bone of a small Dinosaur (Pl. XXX. fig. 1), which was regarded by Bünzel as a Lizard, shows, as I take it, the parieto-frontal suture in front, and an indication that the postfrontal bone was given off from the expanded anterior outer corner, much as in *Iguanodon*. The under and interior surface of the bone, however, is much more lizard-like in some respects, seeing that it did not enclose a brain-case after the pattern demonstrated in *Iguanodon*, *Hypsilophodon*, *Struthiosaurus*, and other genera. The bone was relatively thin, but appears to have been united by a not very intimate suture to bone below, which formed the lateral wall of the brain-case. The bone is imperfect posteriorly, being fractured; superiorly it is divided into three areas:—a median triangular area with concave sides, which becomes narrower posteriorly till it disappears at about the line of fracture (this surface is slightly convex from side to side in front); and two lateral areas for the attachment of muscles working the lower jaw, which converge posteriorly, and in converging are more highly inclined to each other. Their superior limit is sharply defined by a ridge, which becomes elevated posteriorly, and is apparently passing into a median crest, and is also elevated anteriorly at the point where the postfrontal suture is visible. The length of the fragment is 2 centim.; its width in front, as preserved, is 2 or 3 millim. more; its width posteriorly is $1\frac{1}{2}$ centim. There is no foramen parietale. The characters are certainly such that the bone might well be referable to the skull of a Lacertilian; but it would be hazardous to determine absolutely on such evidence whether the bone really pertained to *Mochlodon Suessii*, as is rendered probable by its Iguanodont form.

Scapula (*probably of* Mochlodon).

The imperfect proximal end of a small scapula (Pl. XXVIII. fig. 1) presents somewhat Crocodilian characters. The fragment is only 4 centim. long. It shows the humeral articular surface and part of the sutural surface for the coracoid. The character which especially distinguishes it from Crocodiles is the extraordinary lateral position of the humeral articulation, in consequence of the sutural surface for the coracoid being prolonged beyond it. This articular surface is $2\frac{1}{2}$ centim. long, $1\frac{1}{2}$ centim. wide proximally, and narrower towards the sutural surface. The bone is a little crushed, but was concave from above downward, and flattened in the antero-posterior direction. Hence the surface is narrower, more vertical, and more elongated, and especially more concave than in the Crocodile; but there is a slight angle rising as a short ridge from the hinder exterior corner of the articulation, directed upward and forward, represented in Crocodiles by a similar fainter ridge. Only the posterior part of the coracoid suture is preserved. It makes an angle of 45° with the humeral surface when seen from the front, and an angle of 90° when seen from the side. The bone is narrower in front and behind than in the middle, where it is 12 millim. thick. So much as is preserved is $2\frac{1}{2}$ centim. long. Its external margin is convex; the internal margin appears to have been straighter. At the angle above its union with the humeral surface there is a small depression. Owing to the fact that the bone thickens externally with the humeral surface, the area anterior to that surface is concave and smooth. The concavity is directed obliquely downward and forward. There are indications that the anterior margin of the bone was developed into an angular ridge, which may have corresponded with that of the Crocodile. The visceral surface of the bone was concave from above downward, and, though crushed, appears to have been flatter from side to side, more rounded on the anterior margin, and more compressed on the posterior margin about the humeral articulation than in Crocodiles. The blade of the bone, however, was similarly constricted at the fracture, where it is less than 2 centim. wide and about 1 centim. thick as preserved, convex in front and flattened behind. Though this bone is on the whole Crocodilian in its characters, it is also Dinosaurian, and perhaps makes the nearest approximation to the scapula figured by Prof. Marsh in the fore limb of his five-toed Dinosaurian *Camptonotus dispar*.

STRUTHIOSAURUS AUSTRIACUS, Bünzel.
(See Bünzel, pl. v. figs. 1–6, p. 11.)

The hinder part of the skull of a Dinosaur figured by Bünzel is somewhat difficult to describe, on account of the obliteration or obscurity of the sutures; and yet the anterior surface of the roof of the brain-case is margined by a well-marked transverse suture limiting the front of the parietal bone—a suture similar to that which persists in the skull of the Fowl long after other sutures have become obliterated in the hinder part of the cranium. The specimen certainly presents a remarkable resemblance to the back of the skull of a bird; but I believe that Bünzel has attached more than due importance to this similitude, owing to the circumstance that the true nature of the Dinosaurian skull was even less perfectly known when he wrote than it is now. He has supposed his specimen to be more complete than, in truth, it is, being unaware, or unmindful, of the evidence that, external to the parietal bone, the Dinosaurian skull has an upper arch or bar, like that so common in reptiles and unknown in birds, and that, as a rule, there is also a lower malar arch, more or less developed, behind the orbit; and therefore it happens that the bone which he regarded as tympanic or quadrate, and interpreted as Crocodilian, is the paroccipital or opisthotic of modern anatomists, as, indeed, was long since appreciated by Mr. Hulke in describing his skull of *Iguanodon**. Therefore Bünzel's Avian and Crocodilian affinities of the skull both fall to the ground, owing to this fundamental misconception of its characters. Hence it appears to me desirable to describe the specimen anew, in order to render its structure clearer. The specimen exhibits superior, lateral, inferior, posterior, anterior, and cerebral aspects; and on each of these I propose to offer a few remarks. The fossil, as preserved, is 63 millim. broad behind, and 5 centim. high, owing to the downward direction of the occipital condyle; for, although the skull obviously increases in height as it passes forward, the height from the base to the fronto-parietal suture is only $4\frac{1}{2}$ centim. The presphenoid bone is broken away; but the length from the fracture or suture to the back of the occipital condyle is $4\frac{1}{2}$ centim., and to the back of the supraoccipital bone is $5\frac{3}{4}$ centim. Superiorly and externally the cranial region is moderately convex from side to side, and also exhibits a slight convexity from front to back (Pl. XXVII. fig. 6), especially towards the outer borders, indicative, I think, of the parietal bone just reaching the margin of the temporal fossæ on the right side. The surface of the bone is rough, with slight and irregular close-set elevations, not so distinct as those of a *Trionyx*, but certainly suggesting the surface that is sometimes seen when the scutes are removed from a Chelonian carapace. There is also a transverse furrow running across the bone, rather behind its middle, nearly parallel to the convex posterior border, and therefore curving backward. The width of this superior surface, as preserved, is nearly $5\frac{1}{2}$ centim.; but then the bone is broken on both sides, though it has become thin and separated laterally from the brain-case. Its antero-posterior extent in the middle line where greatest is just over 3 centim. I have no doubt that the transverse groove (Pl. XXVII. fig. 5) indicates the limit of the parietal bone; for the suture defining it is seen on the left side of the cerebral surface and on the external lateral surface; but I cannot trace it across the upper surface, and it may be that the suture is obliterated by ossification, consequent upon a scutal covering. The groove recalls those which occur on the skulls of Lizards such as *Trachydosaurus*, while the texture of the bone is not dissimilar; and hence it is also possible that we have here an explanation of the absence of sutures, in the circumstance that they are covered up by a layer of dermal ossifications. The parietal bone at the frontal suture (Pl. XXVII. fig. 6) is 9 millim. thick; but at the transverse groove the thickness is reduced to 7 millim., owing to cerebral excavation beneath it. The area behind the groove terminates posteriorly in a margin which is rounded, but suggests the idea that a plate 4 millim. thick in the middle, and becoming thinner laterally, was superimposed upon the cranial bones. This region posterior to the groove I suppose to be occupied by the supraoccipital bone.

The posterior aspect of the skull is chiefly remarkable for the elevated border above the foramen magnum, which was evidently

* Hulke, Quart. Journ. Geol. Soc. vol. xxvii. p. 206.

in somewhat close contact with the neural arch of the atlas, and for the transverse grooves and muscular rugosities, which run between this border and the slight groove defining the supposed cranial scute. Hence the back of the skull is not vertical, like that of some Crocodiles, and its superior margin is far from being as well rounded as in very young Crocodiles; and on the whole there is nothing to call for remark as affiliating this region to what is seen in either Crocodiles or Lizards. The surface ascends somewhat obliquely, but in two terraces; that immediately above the ridge bordering the foramen magnum is divided by it into two lateral portions. These lateral portions are channels extending outward and downward, and widening as they go. There are, on each side of the median vertical dividing ridge in these channels, three large tubercles. Above the channels, and as nearly as may be of corresponding size, is a pair of convex surfaces, which are undistinguishable in the middle from the median bar just referred to. They are margined above by the supposed cranial scute, and, as they extend outward, widen and curve obliquely upward; and a muscular ridge appears dividing the outer part of this wedge longitudinally into two nearly equal parts. Hence the pattern of the back of the skull as preserved is very like a capital letter K placed transversely, so that the two diverging limbs correspond to the ridges above the foramen magnum. The height from the top of the foramen magnum to the summit of the back of the skull is 2 centim. The transverse width over the supraneural ridges is 4 centim. The width of each ridge at its outer third, before its upper border becomes concave, is 9 millim., the upper margin extending over the concave channel above it; higher up its width is little more than half. The median connecting ridge between the two transverse ridges at the back of the head is about 12 millim. wide. Though the back of the head as a whole is convex from side to side, it is concave from above downward in the median line. The foramen magnum is slightly elliptical, being 17 millim. wide and about 15 millim. high. The skull presents the unusual condition that the basioccipital condyle retreats below and in front of the upper border of the foramen magnum, so that, placing the back of the skull vertically, which puts the base of the skull horizontal, the back of the brain-case projects for a centimetre behind the basioccipital condyle. The areas at the outer and upper corners of the occipital condyle are concavely notched, and at first convex from side to side, but more flattened as they pass outward and upward. The depth from the back of the skull to the base of the occipital condyle is 4 centim.

The base of the skull, as preserved, is triangular, $5\frac{1}{2}$ centim. from the hinder border of the foramen magnum to the front of the basisphenoid, or a fracture in front of the sella turcica. The hinder border of the triangle is convex, and the lateral border is concave, though all the borders are irregular. There is no sutural distinction between the basioccipital and basisphenoid, any more than between the basioccipital, exoccipitals, and supraoccipital bones. The basioccipital condyle probably is formed to some extent by the exoccipital bones, much as in the Crocodile, since foramina occur some little distance in advance of the basioccipital, which may be presumed to penetrate the exoccipital bones and give passage to the pneumogastric and hypoglossal nerves. The occipital condyle is well rounded; but its outline is subtrapezoidal; its greatest width in the upper third is 2 centim., its greatest depth 16 millim. The under surface is deeply channelled, so that the thickness of the bone behind the articular surface is one millim. The region in front of the occipital condyle is about $3\frac{1}{4}$ centim. long, fairly smooth, but concavely excavated in the middle, both in length and breadth, rising, however, to a rounded margin at the sides internal to the lateral foramina. The width across the pneumogastric foramina is 3 centim. The lateral margin of the triangle is divided by a median convexity into two concavities: the shorter, in front, is about 2 centim. long; and the longer, behind, is a little more; while posterior to this, on the left side, is a surface which appears to have been laterally sutural and nearly vertical, while a suture on the opposite side shows that the upper part of this mass consists of a small bone, which readily comes away. Hence I interpret the lateral masses of bone external to the foramen magnum as being the exoccipital bones, as in Crocodiles, while the small bone above the outer border of the exoccipital is the paroccipital of Owen; and I suppose the exoccipital to extend forward so as to form the side of the wall of the brain-case; so that no portion of the posterior lateral structure preserved can be the quadrate bone, as supposed by Bünzel, and hence the analogy attempted to be made out in this region of the skull with the Crocodile can have no foundation.

I would next note the characters of the lateral aspect of the skull. (Pl. XXVII. fig. 5). Here all the bones which are connected with the roof of the brain-case are more or less broken, and the bones have disappeared which formed the external suspensory arch for the lower jaw, so that nothing remains but the internal part of the head, which may be likened, perhaps, to that of a Crocodilian type in which neither were the quadrate bones blended with its lateral walls nor the pterygoid bones connected with its base. I fail altogether to recognize a Lizard-like type, although, as at present used, the term Lizard is almost large enough to include any thing. Forms like *Amphisbœna*, which have the quadrate bone firmly wedged into the skull and no trace of either of the postorbital arches, might well be regarded as a distinct ordinal type; and there are some Dinosaurs towards which the structures of the hinder part of such a brain-case somewhat approximates; but the cranial bones in ordinary Lizards, like *Iguana*, form a part of the skull that is very imperfectly connected with its roof, and very different from the structure seen in Crocodiles and Dinosaurs, though other Lizards, like *Cnemidophorus* for instance, have a better union between the brain-case and the surrounding bones; but I do not recall any type of Lizard that so far corresponds in the characters of the bones covering the brain with what is seen in Dinosaurs as to justify us in affirming that this skull is lacertilian. Turning our attention first to the basal part of the brain-case, it will be seen that the articular head of the basioccipital is directed almost vertically downward, showing, I think, that the head must have been carried upon the neck as in Deer, Kangaroos, and other animals in which the position of the neck is vertical. The part of the basioccipital posterior to the sella turcica is flattened on its cranial surface, gently concave from side to side, with a slight median ridge. Then at a distance forward of about 3 centim. from the occipital condyle, the brain-case thickens from below upward, but does not present the cup-shaped depression seen in Crocodiles and many birds, though its edge is obviously destroyed by fracture, and must have extended some millimetres higher than the 13 millimetres preserved. At the border of this ridge, on each side, is a large perforation for the second nerve. The inner and anterior wall of the perforation is broken away; and the transverse width between the outer walls of these foramina is 2 centim. Below these foramina, and extending forward, are several others. First, on the right side is a large foramen that runs obliquely outward and forward, penetrating into the brain-case. On the opposite side, instead of one large foramen, there appear to be two, divided by a considerable intervening piece of bone. I have no doubt that this foramen gives passage to the fifth nerve. On the left side it is prolonged backward and outward in a horizontal groove; and although there is a groove on the right side, and though it is smaller and shallower, it does not impress the margin of the bone. In advance of this foramen, and below the sella turcica, in the anterior concavity of the bone, are two other foramina, which appear to be vascular. The anterior one, owing to fracture, is seen on the left side to curve obliquely downward and forward, and open upon the base of the skull. Between the outlets of these foramina, in the median line, is a portion of a conical foramen, the anterior wall of which is removed by the fracture.

The vertical fracture of the sphenoid (Pl. XXVII. fig. 6), where it terminates, is triangular, 2 centim. wide, and about as high, the sides being compressed so as to meet superiorly in a crest which rises in front of the pituitary fosse, as in some birds, and not at all as in Crocodiles. Its walls are concave at the sides; and posteriorly a slight longitudinal ridge rises, which becomes directed at an angle inward and upward to the ridge bordering the pituitary region behind. The pit for the pituitary body is about 12 millim. long and 9 millim. wide, is concave from side to side, and margined by a sharp elevated ridge. Its anterior part is overhung by the process of the sphenoid, which rises above it. The posterior portion of the lateral aspect of the skull consists of a small superior area, subtriangular, formed apparently partly of the parietal and partly of the supraoccipital bones. It is a smooth internal surface below the fractured roof of the brain-case, directed obliquely outward, downward, and forward, and traversed by a groove which probably indicates a suture between the two bones. The posterior border is a sharp knife-edge, concave from before backward. Under this edge a deep excavation extends, penetrating to within half a centimetre of the brain-case. The excavation is smoothly concave, extends longitudinally, and is prolonged backward and outward above the otic bones; but the surface is prolonged obliquely outward and downward, so as to form a smooth quadrate area, which rounds towards the base of the skull, and terminates backward on the left side, where best preserved, in a vertical lunate surface, convex behind and concave in front, formed by the exoccipital and otic bones. In front these spaces slightly converge, especially below and above; and behind the middle there is a foramen a millimetre or two in diameter, apparently largest on the left side, but smaller than might have been expected if it is the entrance to the auditory chamber, which probably lies in the depression above it. From the lateral lunate surface to the inner wall of the brain-case above the occipital condyle is $2\frac{1}{4}$ centim.

Finally there remains the interior cavity of the skull which held the brain (Pl. XXVII. fig. 6). This does not present any great contraction in the auditory region. Its extreme width behind is 17 millim., where the auditory bones bulge inward after the manner of Crocodiles. The transverse width of the brain-case is thus reduced to 13 millim.; but at the same time its height increases from 14 millim. behind to about $2\frac{1}{2}$ centim. in the region of the auditory prominences, though the extreme height of the brain-case is somewhat in advance of this point, where it becomes 3 centim. The width continues to increase from behind forward to the parieto-frontal suture. It is greatest in the upper third of the outline of the brain, where it amounts to 22 millim. A bone which in a bird might be regarded as the alisphenoid, which lies above the sphenoid, appears to meet the parietal and exoccipital by a well-defined suture, visible externally and internally, and running obliquely downward and backward. It is difficult to speak with confidence of the limit of this bone on the external surface, since as it extends backwards it is only preserved on the left side. The suture from which it has come away is well defined on the right side. Its anterior border is sharp; and the external surface is concave from within and outward. This sharp border appears to show that in this Dinosaur the brain-case was not completely closed in front in the middle line. Anterior to the highest point of the upper wall of the brain-case, which lies under the transverse scute-like groove crossing the external surface, the bone makes an angular bend forward; but though there are many little irregularities of outline in the internal surface, there is nothing so important as the bending inward and downward of the lower part of the alisphenoids, which must have made the transverse section of the cerebrum nearly circular at the parieto-frontal sutures.

Imperfect as this description is, it will suffice to show that we have here a Dinosaur of a type so different from that indicated by the skull referred by Mr. Hulke to *Iguanodon*, as only to be classed in a separate suborder; and if the base of a skull figured by myself under the name *Craterosaurus* be, as I believe, also Dinosaurian, that also indicates a subordinal type, and is totally distinct from either of the others. These great differences of skull-structure lead me to suspect that the Dinosauria are a far more important group than has hitherto been suspected *; and it may well be that different genera present modifications which affiliate representatives of the group towards Crocodiles on the one hand and birds on the other. But I cannot believe that any order, however homogeneous, could have spanned the interval between the Crocodile and the bird, though there can be no doubt that this skull of *Struthiosaurus* makes a nearer approach towards the bird than does the skull of any living reptile ; its differences from the bird-skull are precisely those which distinguish it from the Crocodile, little as we know or can infer concerning the suspensory arches for the lower jaw. In the base of the skull not being covered with pterygoids there is a notable difference from Crocodiles of the surviving type ; but then the base of the skull is not bird-like, any more than it is like that of any other animal. It is one of the most distinctive points of the Dinosaurian skeleton.

It would be desirable to compare this specimen with other Cretaceous genera ; but, with the exception of *Acanthopholis*, none of these have, as yet, yielded any evidence of the brain-case. One fragment, found at Folkestone at the base of the Chalk with the remains of the *Acanthopholis horridus*, is briefly referred to by Prof. Huxley ; and on inspection it proves, though clearly allied, to belong to a different genus, a fact that will be best demonstrated by a description of the specimen and comparison of the figures (Pl. XXVII. figs. 6 & 8 and 5 & 7).

Note on the Base of the Skull of *Acanthopholis horridus*, Huxley.

Professor Huxley's account of the skull of *Acanthopholis* is so brief that it would be difficult to be sure from it of the identity of the specimen, especially since Prof. Huxley describes characters which we are now unable to recognize, though it is, of course, possible that the specimen is in a less perfect condition than when originally noticed. I therefore reproduce Prof. Huxley's original remarks (Geol. Mag. 1867, vol. iv., Huxley on *Acanthopholis horridus*, p. 66).

"Of the skull I possess only a very much mutilated fragment, showing the basioccipital and basisphenoid. The occipital condyle measures 1·4 transversely, or has about the same diameter as that of the skull of a *Crocodilus biporcatus* which measures 16 inches in length from snout to occiput. But it is more elongated transversely and excavated above than in the Crocodile, and the exoccipitals enter more largely into its composition. The Crocodilian disposition of the Eustachian tubes is absent ; and the carotids run up the side of the basisphenoid in Lacertilian fashion. The sella turcica has a well-developed posterior plate."

This fragment (Pl. XXVII. figs. 7 & 8) comprises the base of the skull, and includes the basioccipital and basisphenoid, which are completely ankylosed, and give no indication whatever of suture. I am similarly unable to detect any sutural evidence of the exoccipital ; nor can I recognize the basioccipital condyle, which I believe to have been directed

* Professor Marsh, since this was written, has published a classification of American Dinosaurs (Amer. Journ. Sc. vol. xxi. p. 423).

downward, and to have been largely removed by attrition, so that no idea can now be formed of its relative depth. The presphenoidal part of the specimen is broken away and terminates anteriorly in a triangular transverse fracture (fig. 8). The base of the skull, as preserved, is $5\frac{1}{2}$ centim. long. In the middle it is 4 centim. wide, but narrows posteriorly to the region of the condyle, where the bone is 33 millim. wide. Anteriorly it also appears to contract a little; but at both ends the external white film of bone has scaled off, leaving the dark phosphatic substance below—a condition reminding one curiously of the pale and dark mineralization of bones in the Cambridge Greensand. This inferior region is concave in length, with a rounded median ridge, and lateral concavities on each side of it in the middle. Posterior to the middle area the bone is fractured inferiorly for a length of $2\frac{1}{2}$ centim.; and this fracture I suppose to have removed the lower half and characteristic form of the occipital condyle.

The basioccipital bone (Pl. XXVII. fig. 7) terminates posteriorly in a mass which, as preserved, is convex below and concave above, so as to have a crescent outline, and is also moderately convex from side to side. Above it is the brain-case, which certainly extended somewhat further backward than the present limits of the occipital condyle, as is shown by the form and character of the lateral walls. The superior surface, however, of the occipital bone appears to curve convexly downward as it extends backward; and, as preserved, the bone is little over 1 centim. deep, and about 3 centim. wide at the origin of the condyle, which is, as usual, defined by a lateral constriction that can only be detected by careful examination, and is some distance posterior to the lateral notches on each side of the base of the brain-case.

The cranial cavity (fig. 8) is imperfectly defined, because there is no portion of the roof of the brain-case preserved, and its lateral walls are imperfect. It is evident, however, that it is higher than wide; the posterior width in the region of the foramina for the hypoglossal nerves is 28 millim., while the height appears to have been not less than about 4 centim. On the right side a part of the inner wall of the brain-case is exposed, showing that it is smooth, bulges inward a little in the auditory region, and is inclined a little inward as it extends upward. On the left side the bone is fractured, so as to show that the hinder wall of the brain in the auditory region is 2 centim. thick, and extends outward transversely at a little higher level than the base of the skull. It shows a horizontal semicircular canal, which extends from the wall of the brain-case outward and forward for a length of about $1\frac{1}{2}$ centim., as exposed, and is about $\frac{1}{2}$ centim. wide. The curve cannot be followed round; nor can its relations to the other semicircular canals be definitely made out.

Along each side of the floor of the brain-case, and under the transverse jutting of its lateral walls, which extend out horizontally behind, is a row of foramina which extends in a curve, just separated from each other by bony interspaces. Six are visible on the left side; on the right side there were certainly five, and may have been six (fig. 7). These foramina are different from those of *Struthiosaurus* or *Iguanodon*, and furnish a marked character, defining *Acanthopholis*. It may be difficult to correlate them with the foramina in the back of the skull of a Crocodile; but since those perforations are, for the most part, in the exoccipital bones, and extend downward at the back of the skull, it is obvious that we have here in the longitudinal arrangement something more nearly paralleled by Lizards, where the twelfth, eleventh, tenth, eighth, fifth, and second nerves are given off in more or less longitudinal series. The hindermost foramen may be referred to the hypoglossal nerve, the next, perhaps, to the pneumogastric nerve, then perhaps a vascular foramen. The two hinder foramina are much smaller than the third; and the third foramen may probably be for the eighth nerve; the fourth is small; the fifth is so large that it might well correspond to the fifth nerve. The anterior direction of the sixth makes it probable that we have here the foramen for the optic nerve; for though it is somewhat smaller than might have been expected, it is given off from the most anterior part of the side of the brain-case behind the sella turcica.

The anterior extremity of the basisphenoid is massive and wedge-shaped, broken away on the compressed inferior lateral margins, as well as in the front. A strong vertical plate rises in the middle, so as to form the anterior border of the brain-case (fig. 8). The upper margin is $3\frac{1}{2}$ centim. above the base of the skull, and it is nearly 2 centim. behind the anterior fragment of the basisphenoid preserved. This plate therefore seems to me to be exactly in the position of the posterior border of the sella turcica; but if so, the anterior border, such as is seen in *Struthiosaurus* (figs. 6, 5), is entirely broken away. What remains of the sella turcica is a concave base in front of the plate, terminating anteriorly in two diverging concave streaks of bone-surface, which probably represent the channels of the carotids (fig. 8). They extend downward and outward, making an angle of 90° with each other, and do not appear to reach forward. On each side of the posterior plate of the sella turcica there is a concave notch in the skull-wall.

The skull diverges so far from both the Crocodilian and Lacertian types that it may be as well to recognize it as equally distinct from both. It resembles *Struthiosaurus* in the downward direction of the occipital condyle, in the extension of the lateral wall of the brain-case posterior to the condyle, in the transverse horizontal expansion of the exoccipital region in front of the occipital condyle, in the massiveness of the bone in the auditory region, and in the grouping of the foramina, so that the posterior three are inferior, while the anterior three have a more anterior and lateral position; but the convex form of the base of the occipital bone, the immense thickness of the basisphenoid bone, are matter for distinction, as is the form of the alisphenoid in *Acanthopholis*. The resemblances, however, are so remarkable as to show that these two genera are near allies; and though we cannot infer with certainty the roof of the brain-case of *Acanthopholis* from that of *Struthiosaurus*, or the teeth of *Struthiosaurus* from those of *Acanthopholis*, yet they seem to me to show that *Struthiosaurus* was probably a Scelidosaurian, and to open up a suggestive possibility of its claim to the jaws and teeth which have a Scelidosaurian character. Future researches may possibly demonstrate it to be the skull of *Cratæomus*; but as the back of the skull of *Struthiosaurus* is so different from that of *Scelidosaurus*, I have not felt justified in adopting such a view.

Cratæomus.

The dermal armour of this genus presents a remarkable resemblance to that of the Scelidosaurian Dinosaurs. The large supra-vertebral scutes of the caudal region are compressed, and terminate upward in a sharp knife-like edge. They are, perhaps, more like the similar scutes of *Scelidosaurus* than those of *Acanthopholis*. The flat dorsal scutes which were carried on the ribs were also keeled; but the keel was relatively lower, and the plates were more or less ovate. This, too, is a character paralleled in *Scelidosaurus*; but there are also scutes without any ridge at all, and marked with deep vascular grooves. These I regard as probably ventral. Coming probably from the region of the shoulders are two remarkable scutes which are quite unlike any thing at present figured. These plates, which are excavated on the underside, terminated in a sharp spine at each end; and the middle of the scute bore upon its surface a number of conical ossifications, which have much the appearance of a group of limpets packed close together. These ossifications have exactly the appearance of the scutes of *Hylæosaurus*, so much so as to suggest a doubt whether the armour hitherto referred to *Hylæosaurus* may not be unankylosed scutes separated from the plate which carried them, and really referable to *Polacanthus*, in which Mr. Hulke has found an armour closely approximating to that seen in this genus. Finally, there is a scute bearing a bone exactly like the horn-core of an ox; this I am also disposed to refer to the fore quarters. The distinctive features of this armour are the sharpness of the caudal scutes and the form and patelloid incrusting of the cervical scutes; but in other characters it approximates to the genera already named.

The vertebral column is remarkable for the forward extension of the neural arch in the neck and the deep gap between the anterior and posterior zygapophyses, the shortness of the neural spine, and the biconcave form of the vertebræ, while the dorsal vertebræ are remarkable for the great strength of the ridge below the transverse processes, the distinctness of the facets to which the ribs were articulated, and the broad rounded base to the vertebræ. The caudal vertebræ have somewhat the form characteristic of *Acanthopholis*, having a groove in the middle line of the base; but the single lateral ridge is a point of distinction, though the vertebræ were obviously nearly allied to those of that genus. The ribs, in having the superior margin flattened and widened to a greater extent than the depth of the bone, present a character that is found in all reptiles which carried heavy armour, but is especially characteristic of this form, though, according to Mr. Hulke, met with also in *Polacanthus*. The fragments of jaw with the teeth, if rightly referred to this genus, present a character similar to that of *Priodontognathus*, *Scelidosaurus*, and *Acantholis*; but while nearly resembling *Scelidosaurus*, the tooth-structure is distinctive in the character of the serrations, just as the lower jaw is distinctive in its angularity and vascular foramina. But it is the limb-bones which best define *Cratæomus*. The scimitar-shaped scapula, with its powerful acromion process, is altogether distinctive, while what remains of the coracoid appears to indicate an equally unusual form. The humeri are remarkably powerful, and indicate an animal strong in its fore limbs, evidently a quadruped, and therefore presumably carnivorous, since the herbivorous forms have the fore limbs feebly developed. The humerus, with a general resemblance to that of *Anoplosaurus*, is far more robust, and indicates a heavier animal: no bone anterior to the humerus is known. The femur is distinguished from that of the Iguanodonts by wanting the separate external trochanter at the proximal end. It has the articular ends powerfully developed, and, perhaps, most closely resembles in general form that of *Cryptosaurus eumerus* of the Oxford clay. The tibia is remarkable for the extremely compressed form and forward development of the cnemial crest. The fibula, so far as preserved, is very like the fibula of a bird, and bears a similar relation of size to the tibia. The metatarsal and phalangial bones, if belonging to this genus, rather indicate a flattened foot, terminating in claws which were broad rather than sharp. Taken as a whole, far more difference from *Cratæomus* is found in described genera in the structure of the internal skeleton than would have been inferred from either the armour or the teeth; and it is quite possible that the armour, especially in Dinosaurs, may have undergone as little change as the feathers of birds or scales of lizards, so as to be common to several families.

Mandibles and Teeth probably referable to Cratæomus.

Three fragments of the anterior extremities of Dinosaurian lower jaws have been found which indicate two species, though the remains are so fragmentary that they cannot be defined with the detailed accuracy which is desirable. Both specimens are of about the same size, and belong to a genus which is closely related to *Priodontognathus*. I will describe the more perfect specimen first.

This species is represented by a dentary bone (Pl. XXVII. figs. 9, 10), the anterior extremity of which is unfortunately not preserved; nor is the fragment complete on the hinder or lower border, though it probably gives indications of the whole of the teeth. The alveolar border is bent in a sigmoid flexure (fig. 9); and the bone itself is bent so as to present a flattened lower part at right angles to the upper part of the side behind, but sloping more and more outward in front. The lateral contour of the alveolar border is convex, rising higher in the middle and descending to near the level of the base; it has a width of about 6 centimetres. As usual with Dinosaurs, it is higher on the external than on the internal margin. The teeth were placed in sockets defined and separated by narrow bony interspaces. The sockets were circular, and indicate larger teeth in the fore part of the jaw than in the hind part. The alveoli for twenty teeth are shown (fig. 9); they did not reach to the extremity of the jaw; nor apparently was there any bony union between the rami; but the small fragment anterior to the termination of the alveolar margin is broken away. The length of the alveolar margin is about 8 centimetres; and the extreme length of the fragment is under 9 centimetres. The internal aspect of the jaw has at its base a deep groove, which widens from before backward, and passes close to the base of the jaw (fig. 9), though it appears to slightly ascend, and no doubt lodged the opercular bone. The basal margin below this groove is rounded; the surface above the groove is smooth, and forms an obliquely twisted area, which maintains a depth of about $1\frac{1}{2}$ centimètre, so far as it is preserved. It is very slightly convex in length, but concave from above downwards, the concavity increasing forward owing to the increasing twist in the bone. The depth of the jaw at the first alveolus is 18 millimetres. At the tenth alveolus it is nearly 2 centimetres; but the depth cannot be given further back, as the base of the jaw is broken away. The hinder part of the inner alveolar border shows indications of a squamous bone having come awey. This would presumably be part of the opercular bone.

The external surface (fig. 10), as already remarked, is traversed, at least in part, by a strongly elevated ridge, which inclines a little downwards as it extends forward, and dies away towards the anterior end. The surface below this ridge is flattened, but very slightly convex from above downwards, and, so far as preserved, is straight. It shows a few deep narrow vascular grooves and markings for vessels. The superior part of the side is obliquely twisted, becoming more and more horizontal behind, and more and more vertical in front. In the middle of the side, both in length and depth, are four large foramina (fig. 10), placed close together in a line, seven millimetres below the alveolar border, and 7 millimetres above the longitudinal angle in the middle of the bone. These foramina and their interspaces extend over a length of about 28 millimetres. The anterior one descends vertically; the three posterior ones enter the bone obliquely, being directed downwards, forwards, and inwards. From the hinder and inferior corner of the last foramen a slight ridge is prolonged backwards, which makes an angle in the upper margin of the jaw. The surface anterior to these foramina rounds convexly from above downwards; and below the third to sixth alveoli there are about four minute foramina, and below the seventh and eighth, only much nearer to the alveolar margin, two others. It would thus appear as though a series of foramina had extended along the bone, of which the middle four had become greatly developed. The thickness of the jaw from within outwards augments along the line of the median lateral ridge; in front it is about six millimetres, in the middle 12 or 13 millimetres, and obviously increases as it extends further backwards. What remains of the inferior margin, the anterior 4 centimetres, is concave; and the margin curves downwards and inwards as it extends forward. The fourth alveolus is the only one which displays an indication of tooth-structure. It is the extremity of a compressed arrow-shaped successional tooth with serrated border, more after the pattern of that seen in *Priodontognathus* than in any other genus, but too imperfect to demonstrate the generic characters. It appears to be more elongated than the teeth of any genus hitherto described. It may pertain to one species of *Cratæomus*.

The other fragmentary pieces of lower jaws may or may not belong to one individual. A terminal fragment pertains to the anterior end of the right ramus. Two other and smaller fragments belong to the left ramus; but they are so imperfectly preserved as to be scarcely worth notice, although they are apparently quite distinct from the species just described, if I may judge from the flatness of the inferior surface of the jaw and the flatness of the lower part of the side which was vertical.

The anterior extremity of the right ramus was loosely attached, by a rough lunate surface about 17 millimetres deep and 8 millimetres wide, to the ramus on the opposite side. Its extremity is bent a little inwards and downwards—the basal margin being concave from in front backward, and the prolongation of the alveolar margin convex. The fragment is 4 centimetres long; and though upwards of 3 centimetres of the alveolar margin are preserved, I do not recognize with certainty any tooth-sockets. If such exist, they are three in number, and are indicated by small round sockets placed just behind the symphysis; but as the whole anterior end of the bone is covered with vascular foramina, and there are corresponding foramina external to these possible sockets, it is not improbable that they are foramina also, since they present no distinctive alveolar characteristics. The jaw thickens a little in front here; it is bevelled, looks obliquely forward, upward, and, perhaps, outward, and has the appearance of having utilized the foramina in the nutrition of a pad. This surface is about $3\frac{1}{2}$ centimetres long, and above the symphysis is 13 millimetres wide, but becomes narrower posteriorly, where it terminates on the inner edge of the jaw in a sharp margin, external to which two large oblique foramina appear at intervals, the second of which seems to be external to the first tooth-socket, which is compressed from side to side, if it really be a socket, of which there is some doubt. At this point the depth of the jaw is about $2\frac{1}{2}$ centimetres. Below the anterior area described, the upper portion of the side which is smooth begins to be concave from above downwards; and the lower part of the side which is rugose is here convex, though it may, perhaps, as indicated by a fragment already referred to from the other side of the jaw, become flattened in its posterior extension. The specimen shows no trace of the groove on the inferior margin of the inner side seen in the specimen already described; and the appearance of a groove in the upper part probably results from fracture. The internal surface is smooth and concave in length. The thickness of the jaw at the posterior fracture is about 11 millimetres; the base, which is flattened, is nearly at right angles to the internal and external surfaces, and altogether unlike the narrow rounded base which characterizes the species previously described. This, with the less extension of the alveolar margin forward and greater thickening of the extremity of the jaw to form the parrot-like terminal surface, constitute specific distinctions.

Teeth.

The teeth have very much the aspect of having been eaten (Pl. XXVII. figs. 11–16), or at least exposed to some solvent which may have slightly dissolved their surfaces; but the contours are sharp and well preserved; and though the fangs are in some cases broken, the teeth do not exhibit the indications of ordinary wear. It is very difficult, since they only number nine, to judge whether the differences which are to be detected result from relative position in the jaw, or whether one modification at least is not, as I am inclined to believe, of specific importance.

These teeth have a triangular crown and a compressed fang. There is a cingulum at the base on the outer side only; but it merely serves to give a compressed aspect to the base of the crown and to thicken the top of the fang. Even these teeth exhibit certain modifications. First, there is one with the fang perfect; and this shows that it is closed; and on the inner side at the base it curves a little and shows an impressed area, as though a successional germ had rested there; the fang in its upper part is slightly concave from side to side. The tooth is bevelled off obliquely on each side by the cutting-edge of the crown (Pl. XXVII. fig. 13). The other side has a transverse cinguloid ridge, considerably lower in position than the bevellings (fig. 14). It extends up towards the bevelled corners at the sides. The crown is convex from side to side; but the median longitudinal ridge is not distinctly defined. Below the cinguloid ridge the tooth contracts from side to side. The extreme length of the tooth is over 9 millimetres, the extreme width of crown is about $5\frac{1}{2}$ millimetres, and its length down to the base 5 millimetres. The width of the fang becomes reduced to between 3 and 4 millimetres. In a second specimen the crown presents the same characters, only that it is flatter on the cinguloid side. A third specimen has the bevellings on the attached side of larger extent, so as to reach further down the tooth; but all have the crown perfectly smooth, without the slightest trace of serrations on either side. It is quite possible that the bevellings may be produced by wear, though there is nothing to indicate such an explanation.

Then there are two teeth very similar in character, only rather broader in the crown, being fully 8 millimetres wide. These specimens want the bevellings, but have the inner side of the tooth marked, with a narrow middle surface which may be flat or concave, external to which the tooth is bevelled vertically on one side and has a thickening at the base of the crown on the other. The base of the cinguloid thickening on the opposite side is convex in the middle and concave at the sides. Both these teeth are marked with slight rough ridges (Pl. XXVII. figs. 15, 16), which are not continuous to the cutting-edge, and are vertical, and much more marked on one tooth than on the other. Of the two other specimens which have the attached side of the crown flat, one, though but badly preserved, is remarkable for showing a few faint and vertical serrations, which are equally marked on both sides (fig. 12). They did not exceed five in number on each of the cutting-edges, though only one of these is preserved. All these teeth, I suppose, may belong to one species.

There remain two other teeth, which, perhaps, may belong to a second species or may be worn down. They are characterized by the same general features as those already described, but had the crown remarkably low, relatively broad, and hardly making any approach to a triangular form. The tooth is very thick at the base of the crown; and the cinguloid thickening extends along both sides. The crown is smooth, and shows no trace of serration.

I am inclined to refer these teeth to *Crateomus*; they probably belong to the species described.

CRATÆOMUS PAWLOWITSCHII, Seeley.

Vertebral Column.

The vertebral column which I refer to *Crateomus* is chiefly represented by the tail, of which there are about eighteen vertebræ preserved; and the series is very imperfect. There are slight differences of mineralization in these specimens, some being red, others brownish, and some nearly black; and there are slight differences in preservation, since some have the articular margins of the vertebræ rubbed away, and the processes more or less broken, and others are better preserved but somewhat crushed. Still, when the series is arranged in sequence there is a perfect continuity of character and no evidence to suggest that the remains belong to more than one species, or indeed that they may not all have pertained to a single individual. A curious feature, also observed in some of the English Cretaceous Dinosaurs, is the circumstance that these caudal vertebræ scarcely vary in absolute length, though the centrums diminish in size. Hitherto no trace of the sacrum has been found. The dorsal region is represented by two vertebræ, which show the forms of the processes; while the cervical region is represented by a vertebra from the hinder part of the neck. In the absence of evidence of another vertebral column, it may be legitimate to refer these vertebræ to the same species as the tail; and from the similarity of size it is not unlikly that the whole of these vertebral remains are the spoils of a single animal, the *Crateomus Pawlowitschii.*

Cervical Vertebra.

(See Bünzel, pl. ii. figs. 9, 10.)

The centrum and neural arch are both preserved; but the neural spine and transverse processes are broken away. The centrum has the articular faces somewhat oblique; but though this may be to some extent natural, it is probably augmented by crushing, since the form of the centrum has become in this way a good deal distorted. Its length along the base is $2\frac{2}{10}$ inches, while the measurement along the neural canal is about $\frac{3}{20}$ inch less. The posterior articular face, as preserved, is subquadrate, $1\frac{1}{2}$ inch deep, and about $1\frac{7}{10}$ inch wide. It is considerably excavated by a saucer-shaped depression. The anterior articulation was probably as deep, and $1\frac{8}{10}$ inch wide; but it does not appear to have been so deeply excavated as the posterior face. The base appears to have been flattened, and margined on each side by an angular ridge. In the middle these ridges are about $\frac{8}{10}$ inch apart; and they diverge towards both anterior and posterior faces. The sides of the centrum are distinctly defined from the neural arch by the deeply marked horizontal suture, below which in front is the oblong articular face for the rib, which is about $\frac{7}{10}$ inch long and $\frac{1}{2}$ inch deep. It is about $\frac{4}{10}$ inch behind the articular face. It rises as a slight pedicle; and the transverse measurement over these parapophyses is $2\frac{1}{20}$ inches. The centrum is compressed from side to side below these processes, so that a median cavity divides the side into a highly convex upper portion and a comparatively flat lower portion. The articular margin of the centrum is moderately sharp, thickened, and rounded. The neural arch has an aspect of leaning forward obliquely, which is more marked than that of the centrum, and may probably be taken as evidence that the neck of the animal was carried in a somewhat raised position. The pedicles lean forward at an angle of nearly 45°, have their anterior margins concave, and are compressed from side to side, but especially pinched in the middle. The greatest width of the arch in front at its union with the centrum is $1\frac{6}{10}$ inch, while behind and above the middle of the centrum its width is reduced to $\frac{19}{20}$ inch, again to become expanded to $1\frac{1}{2}$ inch near the posterior articulation. This median depression extends up to the side of the neural arch, being margined above and behind by a sharp buttress, which widens laterally and extends outward so as to underprop the transverse process, and form with it the upper head for the rib. Where fractured this process is 1 inch above the capitular articulation, and has a triangular outline pointed in front and about $\frac{4}{10}$ inch deep. There is a triangular area which is concavely excavated behind these transverse processes and in front of the posterior zygapophyses. The posterior zygapophyses are divided from each other throughout their length of an inch by a notch $\frac{3}{10}$ inch wide behind and rather wider in front, where it terminates in the vertical wall of the neural spine, which in the middle has a slight sharp ridge. These processes have their inner sides subparallel, are placed obliquely, and are convex superiorly from below outward. The articular facets are large, subovate, flat, and look downward and outward so as to make with each other an angle which is more than a right angle. The anterior zygapophyses extend entirely in front of the articular face of the centrum. They are similarly divided anteriorly to a level with the centrum, and are thick strong processes which have the articular faces somewhat rounded and convex, as though to allow of considerable play. Behind the facets the bone is a good deal compressed, so as to be concave in length and concave from side to side. The base of the neural spine, as preserved, is a square pillar, rather more than $\frac{1}{2}$ inch in diameter, which appears to rise vertically. In front of this and between the transverse processes is a deep excavation about $\frac{3}{4}$ inch long and wide. The neural canal is large, and formed almost entirely by the neural arch, the neurapophyses converging so as to almost unite in the middle line of the base of the neural canal. The width of the neural canal is greatest in front, where it is $\frac{8}{10}$ inch; and its height is greatest behind, where it is about the same, or a little more, the canal being depressed in front and compressed posteriorly, the width of the canal behind being $\frac{13}{20}$ inch. The height from the base of the centrum to the upper surface of the posterior zygapophyses is $3\frac{1}{10}$ inch; the width over the outer margins of the posterior zygapophyses is $1\frac{7}{10}$ inch; the length, from posterior to anterior zygapophyses is $3\frac{3}{20}$ inch; the width over the anterior zygapophyses was about $2\frac{4}{10}$ inch.

Dorsal Vertebræ.

(See Bünzel, pl. ii. figs. 1–3, pl. vii. fig. 24.)

Of the two dorsal vertebræ the more anterior has the lower half of the centrum badly preserved, but shows the anterior zygapophysis, transverse process, and neural spine completely. In this the transverse processes extend more horizontally outward, while in the later vertebra they are directed more obliquely upward. To begin with the latter (Pl. XXX. fig. 3), the centrum is $2\frac{1}{20}$ inches long, and has the anterior face subquadrate, $2\frac{1}{20}$ inches deep, and $2\frac{1}{10}$ wide. It is moderately concave. The posterior face is badly preserved at the margin, but appears to have been much smaller, since it is $1\frac{17}{20}$ inch deep, and, as preserved, is rather wider. It has a deep pit just below the neural canal, while the remainder of the face is convex from above downward, slightly convex from side to side, and smooth. The neural canal is 2 inches long. The base of the centrum is flattened, margined by rounded lateral ridges. The upper parts of the sides of the centrum are concavely compressed, as though squeezed with the finger and thumb; and here, in the middle of the centrum, the transverse measurement is 1 inch a little below the neural canal. The neural arch is lofty, the height to the origin of the transverse process from the base of the centrum being $3\frac{8}{10}$ inches, and from its base $2\frac{2}{10}$ inches. The buttress which supports the transverse process is flattened at the side, since it is formed by pillars which arise from the anterior and posterior margins of the centrum, and converge as they ascend so as to form a sharp angular ridge beneath the transverse process, which is flattened and expanded above. There is a deep excavation in front of the vertical A-shaped masses which support the transverse processes; and these were placed behind the anterior zygapophyses. There are much larger but similar posterior excavations, which are subtriangular and in front of the posterior zygapophyses, which were divided from each other, and looked obliquely outward and downward so as to form with each other an angle which was much less than a right angle. The neural spine is compressed from side to side, and originates from a base about $1\frac{1}{10}$ inch long. The angle enclosed superiorly by the diverging transverse processes is more than a right angle. The neural canal is subquadrate in front, and about $\frac{17}{20}$ inch wide. Posteriorly its height becomes $1\frac{2}{10}$, and its width about $\frac{6}{10}$ inch. The neural arch has the aspect of being placed vertically on the centrum rather towards its anterior part.

In the other dorsal vertebra the height from the base of the neural arch to the top of the neural spine is $3\frac{7}{10}$ inches. The neural spine is greatly compressed from side to side, rises about $1\frac{1}{2}$ inch above the platform of the transverse processes, is $\frac{2}{10}$ inch in its greatest posterior thickness, has an antero-posterior measurement of $1\frac{2}{10}$ inch, and swells out at its free end to a width of more than $\frac{1}{2}$ inch. This inflated mass is convex from side to side, and tapers forward in a wedge. The platforms of the transverse processes, which are flat above and triangular in section, are given out horizontally; the one preserved measures $2\frac{13}{20}$ inches from the median line to its free end, which is compressed from above downward, and is rounded from back to front. The base of this process occupied the whole space between the posterior and anterior zygapophyses. Its anterior margin is slightly concave, and terminates in a sharp thin edge. The posterior side is similarly thin; but its hinder part is somewhat broken. The width towards the free end is $1\frac{1}{4}$ inch. On the underside is the usual strong median buttress compressed from side to side, and terminating forward in an ovate articular facet for the rib, which is 1 inch long, looks downward and is placed towards the anterior margin; while it terminates inward abruptly on the neural arch above in a nearly circular facet, which is large, vertical, slightly concave, and gave attachment to the head of the rib; half the facet is above the neural canal. There is the usual superior concave excavation in front, behind the zygapophyses, while posteriorly the concavity which runs along the posterior side of the transverse process below terminates in an enlarged excavation; and these excavations approximate so as to be separated only by a sharp vertical ridge which is placed above the neural canal, with which its outline helps to form an S-shaped curve on the right posterior aspect. The zygapophyses present no peculiarities, the facets being flat and oblique; the anterior excavation between the transverse processes in front is small; and the interspace between the two facets for the rib on the sides of the neural arch is about $1\frac{1}{4}$ inch. What remains of the posterior face of the centrum appears to be slightly concave from side to side, and slightly convex from above downward, though this condition has probably resulted from compression. There is here no sharp line dividing the neural arch from the centrum, though the separation can be easily traced, and it is at the middle point of the suture that the compression is greatest; there the transverse measurement is less than 1 inch. The lower portion of Bünzel's figure of this vertebra is the centrum; the transverse process is lettered *d*.

Caudal Vertebræ.

(See Bünzel, pl. ii. figs. 4–8, pl. iv. figs. 6–9, pl. viii. figs. 1, 7, 8, 16.)

There are eighteen caudal vertebræ preserved. The earlier ones have strong transverse processes, which, however, are more or less broken away, are compressed from above downward, and appear to have been short; and the vertebræ differ from each other in passing backward in the suppression of these transverse processes, which become represented by sharp ridges in the middle part of the series, while towards the end of the tail all trace of their existence is lost, and the centrum, which has become gradually reduced in vertical and transverse measurements, assumes a constricted or dicebox-like outline. None of the caudal vertebræ, except the earliest, appear to have possessed a prominent neural spine; for the neural arch has well-developed zygapophyses and a concave outline from front to back. The arch, however, soon becomes reduced in size, and in the middle of the series is greatly compressed from side to side, and the articular zygapophysial facets are lost, while towards the end of the tail the neural arch is a mere rudiment. The chevron bones were at first apparently large, and articulated with large oblique facets at the hinder margin of the base of the centrum; but these facets do not appear to have been quite distinct from each other, though they were partly divided by the median groove on the base of the centrum. They soon become relatively small, and near the end of the tail are quite separated from each other, though (it may be by an injury received during life) they appear to have become united to the centrum. Two of the hinder caudal vertebræ are fractured through the centrum, and show the bones to have contained central hollow spaces, which, however, were not clearly defined by a smooth bony lining, but are rather like the medullary cavities of the long bones of mammals. The articular edges, where preserved, are at first somewhat rounded, but terminate in a sharp outer margin. They are very slightly concave, and later on in the series become almost flat, showing that the tail possessed but little flexibility.

The earliest vertebra preserved has the centrum leaning slightly forward. It is fully $1\frac{7}{10}$ inch long, and the same depth to the chevron facets on the hinder basal margin, which, however, is badly preserved. The width of the centrum in front, at the base of the transverse processes, is $1\frac{7}{20}$ inch. The corresponding width behind is a trifle less. The anterior articular face is nearly flat, but had the margin rounded. The posterior articular face is more concave, and the rounding of the margin is less marked. The upper borders of the transverse processes are on a level with the base of the neural canal. They are placed nearer to the anterior than to the posterior articular face, are transversely oblong where broken close to the centrum, and measure $\frac{8}{10}$ inch in length, $\frac{4}{10}$ in depth. Below them the centrum is compressed; the base is broad, ill defined, 1 inch in width, rounds into the sides, and is divided longitudinally by a shallow groove about $\frac{3}{10}$ inch in width, which is most marked posteriorly. The neural canal is high and narrow: the sides of the neural arch converge upward; and the anterior zygapophyses have the facets looking inward; they are concave in depth.

The second and third vertebræ of the series only differ in having slight tubercles adjoining the anterior and posterior articular margins on the middle of the sides, and in the decreasing dimensions of the centrum and processes, though the length still remains the same. The fourth vertebra is distorted by vertical compression, and the fifth by lateral compression. It, however, has the neural arch well preserved, and shows the length from the anterior to the posterior zygapophyses to be $2\frac{13}{20}$ inches. There is also an indication of a slight neural spine broken away, which rose above the posterior zygapophyses. The greater part of both anterior and posterior facets projects beyond the centrum. The anterior pair of facets is divided from each other; but there is only a slight notch at the hinder extremity of the posterior pair. In the sixth vertebra the neural arch is seen to taper posteriorly, when seen from above, in a triangular outline slightly compressed in the middle; and in the seventh, in which the centrum is $1\frac{8}{10}$ inch long, $1\frac{4}{10}$ inch deep posteriorly, and slightly wider, the neural arch is $2\frac{4}{10}$ inches long. There is a distinct concave compression below the anterior zygapophyses, from which faint ridges extend backward longitudinally towards the posterior zygapophyses. The facet from which the transverse process has come away is still ovate, about $\frac{7}{10}$ inch long, and is placed in the middle of the side of the centrum, just below the neural arch. The neural spine is seen to be a slight sharp ridge. The anterior zygapophyses are $\frac{11}{20}$ inch apart, while the posterior zygapophyses, which have smaller facets, are $\frac{4}{10}$ inch long. The groove on the base of the centrum has become somewhat narrower and more sharply defined. Here several vertebræ appear to be missing; and in the next of the series the transverse process has become much smaller, is placed lower on the side of the centrum, is margined by a vascular groove in front, and is prolonged backward by a sharp ridge towards the articular margin. The vertebræ now begin to elongate a little; and the ninth of the caudal series is $1\frac{9}{10}$ inch long; the transverse processes have disappeared, and are only marked by a sharp median ridge in the middle of the centrum, margined in front by an oblique vascular groove. Above these lateral ridges the centrum is compressed from side to side; the basal groove has become much shallower and best marked towards the extremities. The tenth and eleventh show the neural arch to be greatly compressed from side to side, and to rise very much higher behind than in front, owing to the greatly diminished size of the anterior zygapophyses. The posterior zygapophyses have disappeared; and the centrum is a good deal constricted in the middle. The twelfth centrum shows a much greater reduction in size of the neural arch, which leaves the posterior third of the centrum free. The underside of the centrum is similarly compressed to the upper part, though the median basal ridges become rounded. The facets for the zygapophyses are distinctly marked at both ends, and divided by a groove, of which there is no trace in the middle of the base. In the thirteenth and fourteenth vertebræ the centrum is $1\frac{7}{10}$ inch long, with the articular face $1\frac{3}{20}$ inch wide in front and rather less behind, while the depth in front is 1 inch. The neural arch is small, and its superior outline horizontal. The measurement from the middle of the base of the centrum to its upper border is $1\frac{3}{20}$ inch. The neural canal indents the centrum concavely at both back and front articulations; and from the hinder limit of the neural arch a vascular groove impresses the sides, descending slightly forward to the middle of the base. The centrum here is most constricted, and measures $\frac{8}{10}$ inch from side to side, and has a rather less depth. The chevron bones are preserved in the thirteenth vertebra, with the posterior margin of which they appear to be blended; they unite below in a V-shape, and have facets for the succeeding vertebra. They are $\frac{13}{20}$ inch wide, $\frac{11}{20}$ inch deep, and, with the groove at the terminal end of the centrum, enclose the vascular canal. Of the fifteenth vertebra only half the centrum is preserved. The sixteenth and seventeenth are blended together, and the chevron may not have united in the median line. The vertebræ now become roughened with many slight longitudinal muscular ridges, indicative of the near approach of the end of the series; and the articular faces of the centrum appear to have central concavities.

Ribs.

(See Bünzel, pl. iii. figs. 5, 6, pl. viii. figs. 14, 15, pl. i. fig. 27.)

One cervical rib is preserved; there are about half a dozen tolerably perfect dorsal ribs, and a multitude of fragments of dorsal ribs. The majority of these obviously belong to one animal; and I refer them to the smaller of the two large Dinosaurs, *Cratæomus lepidophorus*; but there are a few slightly larger fragments which possibly pertain to the larger Dinosaur. They are, however, too imperfect to yield any characters for description; and as they are doubtful remains, I prefer to leave their elucidation to future discoveries. They are larger and stouter than the bulk of the specimens. The only example which shows the proximal end is represented in Pl. XXXI. fig. 12, and may be compared with the corresponding part of the smaller rib, fig. 17, Pl. XXVII. This proximal end is the specimen figured by Bünzel as the lower jaw of a lizard, a determination which is presumably due to its imperfect condition and the circumstance that the transverse platform is only developed on one side. I owe its identification to Mr. Hulke, who recognized its resemblance to the smaller specimens when examining the collection.

The cervical rib wants the articular head of the lower tubercle. The interspace between these two heads was nearly $1\frac{1}{2}$ inch, the outline between them being deeply concave; the ventral outline is flat, the dorsal outline concave. The length of the rib, as preserved, is $3\frac{2}{10}$ inches. After being directed outward for half its length, it curves concavely backward and tapers at the same time. There is in front, in the middle of the rib, a slight ridge. The articular head which is preserved is $\frac{6}{10}$ inch long and $\frac{9}{20}$ inch wide. When perfect

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the rib must have had a Y-shaped form; and just below the fork of the Y on the posterior side is a moderately large vascular foramen.

The dorsal ribs are all imperfect at the distal end; and some of them have a much greater curve than others. The longest fragments are imperfect, proximally and distally, and measure round the outside curve about 11 inches, and across the chord a little over 10 inches. But all the ribs agree in distinctive character, which is seen in side-to-side compression along the proximal half of the visceral surface and lateral expansion on the dorsal surface (Pl. XXVII. fig. 17), so that in this half of the rib the transverse section is shaped like a T (Pl. XXVII. fig. 18); but distally the rib expands on the visceral surface, and the elevated ridge on the anterior border disappears, the direction of the rib becomes somewhat oblique, and its section has a compressed ovate outline. One consequence of this remarkable dorsal expansion is to form an expanded table-like external surface which is convex in the direction of the length of the rib, and nearly flat in the antero-posterior direction; so that the ribs closely resemble the combined rib and costal plate of a Chelonian, and in the living animal the interspaces between the ribs must have been as small as in many mammals, such as the Buffalo and the Lesser Anteater. It is, of course, possible that this expansion of the dorsal margin of the rib may be homologous with the costal plates of Chelonians, since representatives of the structure are also met with in Crocodiles, *Hatteria*, and birds. I have no doubt that this table structure carried the heavy dermal armour with which these animals were weighted. One specimen (fig. 17), which has the articular head preserved, has an interspace of $1\frac{3}{10}$ inch between the capitulum and tuberculum. The capitulum curves slightly forward, is $\frac{11}{20}$ inch in depth, and gradually widens on the ventral surface towards the articulation, where it is $\frac{1}{2}$ inch in diameter. The tuberculum is relatively small, $\frac{1}{2}$ inch from back to front, and about $\frac{1}{4}$ inch in width. It is somewhat reniform and rounded, like the outside of a kidney. Immediately beyond the tubercle the bone begins to widen; and the anterior ridge extends in the specimen 4 inches, while in other ribs it extends 6 inches, and in some only 3. Its antero-posterior width is also variable, but, where widest, in no specimen measures more than 1 inch, and is usually about $\frac{3}{4}$ inch. The compression of the rib just below the tubercle gives a measurement of less than $\frac{2}{10}$ inch, though in some specimens it may be a little more and in others less; while the depth of the rib from dorsal to ventral surface is at first $\frac{9}{10}$ inch, and becomes gradually reduced as the rib extends and loses its T-shaped section. The side-to-side compression extends close under the external platform, so that both sides of the rib are concavely channelled. Several specimens show some amount of muscular roughness on the transverse platform and a part of the rib distad to its termination; and this is probably correlated with the muscular attachment of dermal armour. The longest ribs preserved do not indicate a greater length when complete than 14 inches. When they become obliquely flattened they maintain a remarkable uniformity of width, and taper almost imperceptibly towards the distal extremity.

Dermal Armour.

(See Bünzel, pl. iv. figs. 1, 2, pl. vii. figs. 20, 21, pl. viii. figs. 9–12.)

The Dinosaurian dermal armour which I refer to the genus *Cratæomus* presents many remarkable modifications, such as have not been met with in any genus hitherto described. Some of the plates are remarkably similar to those of *Scelidosaurus* and *Acanthopholis*; others are large scutes with a median longitudinal ridge and numerous vascular impressions on the carinate surface, as though they were imbedded in the skin. These plates are all thin and may have been abdominal, while the more elevated plates may have been dorsal and caudal. A third type of plate appears to be greatly compressed from side to side with a sharp cutting surface in front, terminating in a spike superiorly, and with a rounded posterior margin. The articular bases of these plates are not preserved. A fourth kind of plate of large size appears to have terminated at each end in a great triangular spike, while across the intermediate space there extended rows of conical tubercles somewhat resembling in outline those attributed to *Hylæosaurus*. A fifth kind of armour is represented by an immense conical spine, like the horn-core of an ox, which rises from a bony base.

None of these pieces of armour are symmetrical, hardly any of them can be grouped in pairs; altogether there are fully fifty well-defined plates, besides a large number of fragments. It is quite possible that the remains may have belonged to more than one species. But seeing that the vertebral column of one species is well preserved in its hinder portion, and that to this species the bulk of the limb bones may reasonably be relegated, and that in many points of osteology there is an approximation of the animal towards *Scelidosaurus*, we may be justified in considering that the larger Austrian Dinosaur possessed armour as varied in character as that seen in its English prototype; and in the absence of a second and larger vertebral column, I am unwilling to attempt to divide the scutes between the two different animals, merely on the ground of their contours. Yet it may be acknowledged that the horncore-like scute is larger than would have been expected, and that the whole armour is heavy even for an animal with such strongly marked muscular development as is shown on the bones of the limbs of both the species.

I proceed to describe the armour according to the varieties it presents. As Prof. Suess had noticed, there is, besides the horn-like scute, a second base, from which the horn-like spine has been broken away. There thus appear to have been at least a pair. The base from which the horn rises (Pl. XXVIII. fig. 4) is $5\frac{1}{4}$ inches long, of irregular oblong shape with roughened edge, a little broken at one end. It is nearly $3\frac{1}{2}$ inches wide where widest, and narrows to about $2\frac{1}{2}$ inches. It is concave in length on the under surface in the middle, convex at the sides. The margin is full of vascular perforations, and appears to have had strong union with the skin. On the broad side this bony base is $1\frac{6}{10}$ inch thick: on the narrow side the greatest thickness is $1\frac{3}{10}$ inch. The horn-like spine is placed obliquely upon it, and rises vertically, curving a little backward or outward. It is $5\frac{1}{2}$ inches high. Its base is rather more than $2\frac{1}{2}$ inches long, and $2\frac{1}{10}$ inches wide. The spine is slightly flattened on the convex and concave sides. The right and left sides are nearly straight. The bone is covered with close-set irregular vascular perforations similar to those on a horn-core. (See Bünzel, pl. v. fig. 10.)

Two other plates of quite as remarkable character are dissimilar in form, one being twice the width of the other; but both had smooth bases for attachment to the skin. The base is rounded at its lateral margins, as though it were a bone distinct from the extraordinary dermal ornament which rises from it. The larger specimen (Pl. XXVIII. fig. 2) is 8 inches long and imperfect at one end. The articular base appears to have been about $4\frac{1}{2}$ inches long and 2 inches wide, while the greatest width of the plate is $3\frac{1}{4}$ inches towards each end of the articular space, and in the intermediate area it becomes contracted to about $2\frac{1}{2}$ inches. The spine which existed at the other end of this contracted area has been almost entirely broken away; so that the plate was originally probably a central oblong mass with constricted sides terminating at each end in a large triangular spine, which was directed upward from the body of the plate. The one spine which is preserved is on its upper surface about 4 inches long, and at the base $3\frac{1}{4}$ inches wide. It is slightly convex from side to side, and terminates in a sharp cutting-edge on each side, which is longer and more convex on one side than on the other; and the longer edge is reflected a little upward. There are a few longitudinal subparallel vascular grooves in the middle of this part of the plate. On the under surface of this region the bone is flattened on the two sides, which converge towards a rounded ridge in the middle line, which helps to give strength to the sharp dagger-like extremity in which the bone terminates. The greatest thickness of this part of the plate in the middle is $\frac{17}{20}$ inch. Its base terminates abruptly, perhaps owing to some crushing on the underside. The middle oblong portion of the plate is studded over with conical tubercles, the bases of which are pretty clearly defined, and the cones are low. They are arranged across the bone in three rows with four low conical tubercles in each of the two outer rows and two larger tubercles in the middle, 1 inch in diameter, with three on the external margin of each, making in all 6 in the middle. These tubercles make an elevated border abutting against the triangular spine. Their surfaces are roughened with close-set irregular vascular punctures. The smaller plate (Pl. XXVIII. fig. 3), of similar character, is rather better preserved, its total length $6\frac{1}{2}$ inches, length of the articular base $5\frac{1}{4}$ inches. It carries a vertically elevated spine, and the base beneath this is deeply concave. The margins of the base are smooth and well rounded as already described in the larger specimen. The width of the base is $1\frac{3}{20}$ inch. At one end the compressed spine rises at an angle from the part of the plate on which it is situate; it is somewhat fractured; but its height as preserved is nearly $2\frac{1}{2}$ inches, and the length of its base rather less; it terminates towards the free extremity in a sharp cutting-edge. Its thickness in the middle of the base is $\frac{9}{10}$ inch; and it tapers upward and outward towards both margins. It is defined at the base by a constriction which appears to separate it from the plate from which it rises. It is scored with somewhat irregular vertical vascular furrows. The corresponding plate at the other end is much smaller, and is defined from the under articular surface by a furrow; and a similar furrow appears to mark its limit on the upper surface, as though it did not completely cover the bone upon which it rests. It is of ovate outline, $2\frac{2}{10}$ inches long and $1\frac{1}{4}$ inch wide in the middle. Its surface is undulating, as though the free extremity, growing against another plate, had been forced up into an elevation. It has the aspect of projecting on one side beyond the bone on which it rests, and is then sharply compressed, and terminates in a cutting-margin which is convex in length. The interspace between these terminal plates is rhomboidal, about $1\frac{9}{10}$ inch in length, and is covered with conical tubercles, the largest of which is $\frac{7}{10}$ inch long and about $\frac{1}{2}$ inch high. These tubercles are about 5 in number, the 3 largest being on one side.

The next series of dermal bones are all longitudinally carinate. They may, perhaps, be divided into such as have the base angularly excavated, as though they were median bones of the dorsal or caudal region, and such as have the base comparatively flattened; and in these latter the keel becomes greatly reduced in height: these bones are probably lateral. Judging from the example of *Stagonolepis*, I am inclined to believe that most of these plates pertain to the tail. There are four plates, each about $2\frac{9}{10}$ inches long, with an ovate base having a rough margin, rising into a sharp cutting median keel about 2 inches in height, which has a vertical sharp margin behind and a convex margin over the length of the plate (Pl. XXX. fig. 2). The sides of these plates are concave from above downward, and convex in length; but they are all somewhat distorted by pressure. They thin away at the free margin to about $\frac{1}{10}$ inch in thickness. Four other plates, also angular on the underside, are much more elongated, and clearly overlap each other at one end, which may be presumed to be posterior. The largest of these plates is $6\frac{3}{4}$ inches long, $1\frac{13}{20}$ inch wide where widest behind, and $2\frac{1}{2}$ inches high in the highest part of the sharp compressed keel. One side of this plate is moderately concave from above downward; the other side is plano-convex; and posteriorly the underpart of the bone has the aspect of being obliquely truncated—a character which results from the posterior $2\frac{1}{2}$ inches rising free from the basal attachment so as to terminate in an upward and backwardly directed spine, which overlapped the next succeeding plate. The crest of the median ridge has a very slight sigmoid flexure. Attached to this bone on one side is a small fragment which appears to be a broken portion of the proximal end of the dorsal rib. Other plates are somewhat flatter and relatively broader;

one which measures nearly 5 inches in length has a subrhomboidal outline, two long sides converging in front, and a short pair of sides converging behind. The greatest width of the plate is $2\frac{1}{2}$ inches. The greatest length of the flat part of the base is $3\frac{1}{2}$ inches; and the posterior $1\frac{1}{2}$ inch rises into a strong spine, which terminates the median crest, is $1\frac{9}{10}$ inch high, compressed behind and above. The crest gradually diminishes in height from this spine forward till it dies away at the anterior end. The outline of the crest is very slightly sigmoid. The crest has a compressed aspect, as though it had been naturally squeezed from side to side in its upper half.

There are numerous smaller sharply carinate plates of a somewhat ovate outline, with the keel placed nearer towards one margin than the other, and always becoming a little more elevated towards one end, where it is truncated. And these plates, though mostly flat on the underside, always have the end on which the ridge is highest bent a little upward, as though to overlap the next succeeding plate. These plates vary in size: one is $2\frac{8}{10}$ inches long, $1\frac{6}{10}$ inch wide, and has the keel $\frac{13}{20}$ inch high; another is $2\frac{3}{10}$ inches long, $1\frac{7}{10}$ inch wide, and has the keel $\frac{8}{10}$ inch high posteriorly.

Another remarkable series of plates is distinguished by extreme thinness. They appear all to have been subrhomboidal and to have had the keel scarcely elevated.

The largest is about $2\frac{7}{10}$ inches long, and more than $2\frac{3}{10}$ inches wide. The under surface is smooth and slightly convex. The superior and inferior margins converge to a sharp but irregular edge; the thickness of the body of the plate is about $\frac{3}{20}$ inch, though many of the plates are much thinner; and the thickness in the line of the median ridge is about $\frac{3}{10}$ inch. This slight keel does not extend to either extremity of the plate; but the margin of each plate is turned up towards one of the posterior sides, as though they still obliquely overlapped (Pl. XXXI. fig. 3). The surface of these plates is slightly concave on each side of the median ridge, and there scored with vascular markings which ascend towards the ridge and ramify and interlace. Their prevailing direction in the plates with more elevated keels is towards the posterior spine. There are a few slightly thicker plates which have no trace of keel, but are flat below and gently convex above (Pl. XXVIII. fig. 5), with a deep Y-shaped vascular groove on each, and a sharp margin. The smallest and best-preserved is $1\frac{4}{10}$ inch long, and $1\frac{1}{10}$ inch wide.

Some fragments of crest-spines, broken away from the bases, indicate plates of a larger size than any thing here described. The plates appear to have been remarkable for their great side-to-side compression, the posterior elevation of the crest, and the sharpness of the spine, which, in fragments preserved, extended to a height of 5 inches where the antero-posterior measurement is only about 3 inches, and the greatest thickness of the spine from side to side is only $\frac{13}{20}$ inch (at the inferior fracture).

There is also a fragment indicating that the plates in which the keel is almost suppressed, in some regions attained a larger size than has here been described.

One such fragment as preserved is about 5 inches long and rather wider, with apparently two slight keel-like ridges parallel to each other. The greatest height of the crest in this specimen is about $\frac{15}{20}$ inch.

If all this armour is correctly referred to the genus *Cratæomus*, it furnishes one of the most distinctive generic characters of this type. I do not remember any described genus in which large tubercled plates such as are here figured have been found, though an isolated plate was described from the Wealden of the Isle of Wight many years ago* as showing a not dissimilar ornament. Other plates are so similar to armour of *Scelidosaurus*, especially the median-keeled caudal plates, as to enable us to concur with Bünzel in recognizing a strong affinity to that genus, which, however, does not amount to identity. *Cratæomus* was more heavily armoured. It is difficult to say whether its armour has more in common with the bony tubercles which occur on the limbs and tail of many Chelonians, or approximates better to the bony scutes of certain lizards and crocodiles; for it is so distinct that no near parallel can be drawn between the armour of Dinosaurs and that of living reptiles; nor if the comparison were possible would it have much weight as a mark of organic affinity.

Scapulæ.

Three specimens of Dinosaurian scapulæ have been obtained; two are larger than the other, and belong to a distinct species. The two larger specimens were figured by Bünzel, and regarded by him as left ribs of his imaginary Lacertilian genus *Danubiosaurus* and the type of his species *D. anceps*. They are left scapulæ. The smaller specimen obtained subsequently is a right scapula. I refer the larger bones to the animal indicated by the larger limb-bones (*Cratæomus Pawlowitschii*), though, as the smaller specimen is little more than half the size, the disproportion in the scapulæ is much greater than would have been anticipated in the two species.

Left Scapula.

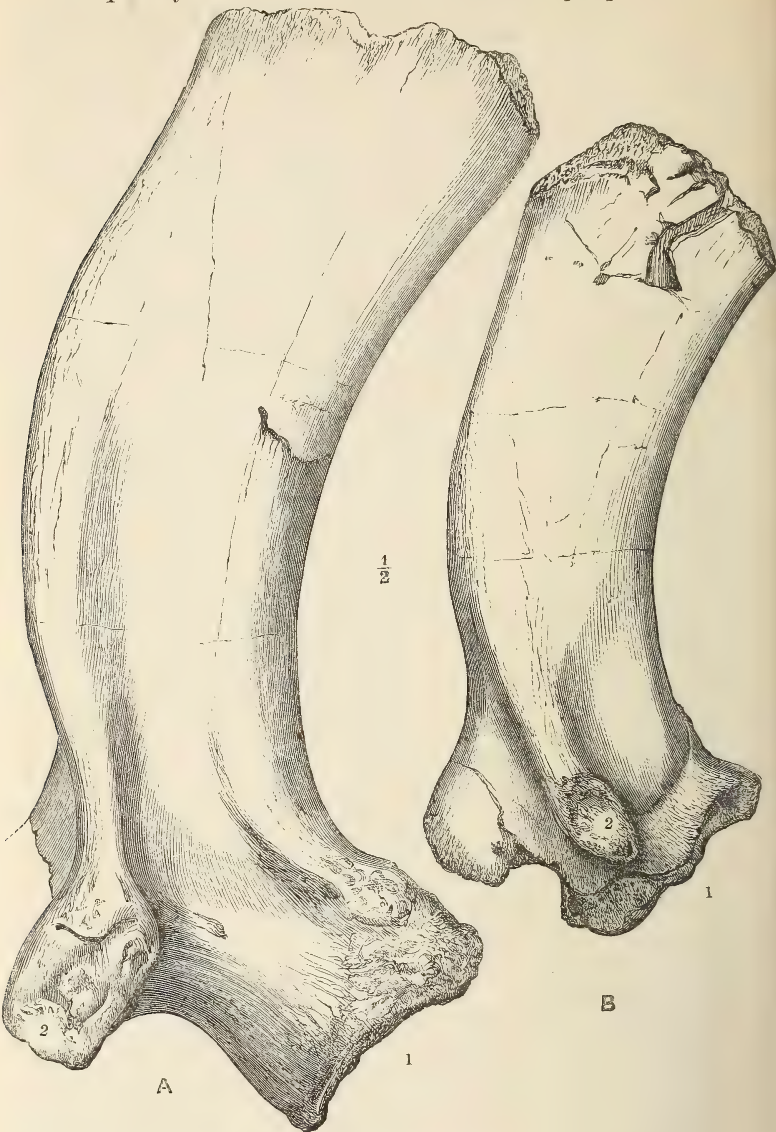
(See Bünzel, pl. v. figs. 7–9, pl. vi. figs. 1–3.)

The scapula (fig. A, p. 656) is remarkable for its great breadth, its curved form, its compressed aspect, and the remarkable acromial process in which its slight spine terminates. The specimen has been a little crushed, and is not quite perfect at its distal end; the whole surface for union with the coracoid is destroyed by decomposition, and slightly injured by fracture. What remains of the articular surface for the humerus is a semiovate surface $5\frac{1}{2}$ centim. wide and rather longer. It is margined by an elevated ridge, has the usual roughness of cartilaginous surfaces, and is more concave than usual, both in length and breadth. The inner or visceral margin of the bone appears to have been more convex than the external margin. Both are somewhat inflated; and the external surface and posterior margin

* J. E. Lee, Ann. & Mag. Nat. Hist. vol. xi. p. 5, reprinted in his 'Note Book of a Geologist.'

especially are roughened with ligamentous attachments and muscular rugosities. The thickness of the bone rapidly diminishes above the articulation; and it continues to become thinner towards the free end, where the thickness does not exceed a centimetre and a half. The posterior margin is compressed and rounded, the rounding becoming more conspicuous as the surface approaches the humeral articulation, owing to the increasing thickness of the bone. The length of the posterior side of the bone is about 25 centim.; its outline is concave; the concavity, as preserved, may be indicated by the fact that the chord joining its two extremities is 21 centim. long, and the abscissa 6 centim. high. The corresponding anterior margin is not quite parallel, since the bone is wider in its upper third than in its lower third; and hence the anterior margin is more convex. The least transverse measurement above what may be termed the spine of the scapula is $6\frac{1}{2}$ centim. In the upper third of the bone the width has increased to upwards of 8 centim.; it then contracts a little to less than 8 centim., so as to make the anterior termination of the superior margin concave; for the bone widens once more, so as to become broader than ever at its free end. The posterior corner of the free end appears to be curved a little outward. The external surface is smooth, convex in length, and more convex in breadth at the distal end than proximally. The visceral surface exhibits corresponding characters. The anterior margin of the bone is thicker, better rounded than the posterior margin, and rougher with muscular attachments. As preserved, the measurement from acromion to the anterior distal margin is 23 centim. in a straight line. In about the middle of the anterior margin the bone becomes appreciably thickened on the inner side with muscular attachments, and the thickness increases until a vertical anterior shoulder is formed almost at right angles to the spine of the scapula, extending downward and inward towards the coracoid area. Only a small portion of this triangular space is preserved; but so much of it as is seen below the acromion is 4 centim. deep. The spine of the scapula only runs for a short distance along the proximal part of its surface, and is difficult to define, because the bone is obviously compressed so as to make the surface posterior to the spine appear more concave than it really was; but the spine may be considered to originate in the thickening of the anterior margin of the bone already alluded to; and it becomes most distinct a centimetre or two above the acromion, where it is $1\frac{1}{2}$ centim. wide, flat above, and margined at the sides by rounded ridges. It is prolonged into a free process or acromion, which was directed forward and outward. This process is a little crushed, is nearly 5 centim. long, 33 millim. broad, and, as preserved, about 2 centim. thick, though before crushing it was thicker; the corners and angles of its free end are rounded; and the inferior or internal surface is concave, since it rises from the anterior coracoid border of the bone. The plane of the acromion is parallel to that of the blade of the scapula, and makes an angle of 45° with the direction of the humeral articular surface. The distance

Scapulæ of Cratæomus Pawlowitschii *and* C. lepidophorus.



A. Left scapula of *Cratæomus Pawlowitschii.*
B. Right scapula (drawn reversed for comparison) of *Cratæomus lepidophorus.*
1. Humeral articulation. 2. Acromion process.

of its inferior border from the humeral articular surface is between 6 and 7 centim. From the inferior margin of the acromion descends a strong rounded ridge which divides the part of the bone above the humeral articulation into anterior and posterior areas, and, but for the intervening acromion process, would look like a continuation of the spine. This ridge dies away before reaching the humeral articulation. Posterior to the acromion the surface of the scapula is broadly channelled. In its singular curvature and development of the acromion it is unlike the scapula of any other Dinosaur.

The second specimen, though evidently belonging to the same species, is a little smaller; it has been reconstructed out of even a larger number of fragments than the specimen described. The proximal part of the bone is wanting, the fracture having removed the articular region and acromion process; but this portion was compressed from side to side; the anterior margin of the bone, however, appears to be thicker, and the cavity in front of the acromion is more marked, than in the specimen here figured. Distally a portion of the terminal free margin of the bone is preserved, showing that it was obliquely truncated and somewhat thickened and roughened with muscular attachments, especially towards the posterior border; the specimen, as preserved, is 27 centim. long and about 76 millim. wide in the blade, where it is widest. The details of the two bones otherwise present the closest agreement.

Distal End of Humerus.

A large humerus is unfortunately only known from its distal end (Pl. XXIX. fig. 4), which has decayed in the manner so frequent with these fossils, and as though indicating that the terminal end had been a distal epiphysis similar to that which characterizes the long bones in the order Sauropterygia, which may have separated from the shaft absolutely or decayed in consequence of the less perfect ossification of its cartilaginous substance.

This fragment is little more than 4 inches long. It exhibits at the proximal end a natural fracture, made during extraction from the rock; and here the bone is $1\frac{9}{20}$ inch thick, $1\frac{8}{10}$ inch wide, ovate in outline, with an angular bulge towards the middle of the superior surface—a bulge which indicates a ridge similar to that referred to in the more perfect specimens of the other species (Pl. XXIX. fig. 1). I regard this specimen as the distal half of a left humerus of *Cratæomus Pawlowitschii.*

The fracture is somewhat interesting as showing the existence of a central medullary cavity (Pl. XXIX. fig. 5). This cavity is $\frac{7}{10}$ inch long and more than $\frac{1}{2}$ inch wide; so that the bone round it is about half an inch thick; and this contrasts remarkably with the thinness of the terminal and irregular edges of the distal margin of the shaft, which is nowhere much more than $\frac{1}{10}$ inch thick, though becoming somewhat thicker as it extends proximally. The cavity is relatively smaller in the second species. The superior surface is unfortunately somewhat crushed; and the whole specimen has been pieced together, like so many of these remains, with great patience, skill, and success. The shaft does not widen quite so rapidly towards the distal end as in the smaller species, since the bone is $2\frac{1}{2}$ inches wide only at $2\frac{1}{2}$ inches further towards the distal extremity. The surface is remarkably smooth and free from muscular markings, except on what I regard as the outer side. This is roughened; and rather above its middle there is a chain of strong muscular eminences (which appear to be much in the position of the inner straight ridge described in *Cratæomus lepidophorus*, in which, however, the ridge was only developed proximally). Here it is strong distally, and would seem to have extended to the terminal articulation. The middle of the inferior aspect is marked by a straight vascular groove about an inch long in the upper half of the fragment; and at the extreme distal margin towards the inner side there is a vertically ovate muscular pit about 1 inch long. The distal extremity appears to be curved downward and outward rather more than usual, while the surface is more than usually convex. The sides, which are slightly concave in length, are comparatively straight. The extreme width, as preserved distally is 3 inches; but this is fully 1 inch short of what must have been the end of the specimen.

Femur.

(See Bünzel, pl. iii. figs. 2–4.)

The shaft of the right femur which I refer to this species is very well preserved; but there is no trace of the articular extremities, which disappeared before the bone was imbedded in the matrix; and towards the articular ends the bone is crushed, on the posterior aspect proximally, and at the distal end in front. There is, however, quite enough preserved to indicate a very distinct animal from that referred to *Cratæomus lepidophorus* (Pl. XXXI. fig. 5), to which, however, it was nearly related in femoral character. The fragment (Pl. XXXI. fig. 1) is 11 inches long and $1\frac{7}{10}$ inch wide in the lower third of the shaft, is remarkably cylindrical, has the muscular ridges on the anterior surface strongly developed, while the inner middle trochanter of the shaft would not be recognized as such, so feebly is it developed, were it not for the characters of the other species. As preserved, the appearance of the bone is remarkably mammalian. When perfect, it may have been 15 inches long.

The fragment of the corresponding left femur is scarcely at all compressed, but was so far destroyed before mineralization that only 7 inches of its length now remain, showing the lower half of the shaft to be subtriangular in section, being flattened behind and somewhat compressed towards the median muscular ridge in front.

The following description is drawn from the representative of the right limb (Pl. XXXI. fig. 1). The bone, which is most constricted in the lower third, widens in the usual way towards both proximal and distal ends; and its most remarkable feature is the inflation of the proximal half of the dorsal or anterior half of the shaft in the line of the median longitudinal muscular ridge. This ridge is strong; and its crest is broken into short lengths of from half to three quarters of an inch; it originates distally in the part of the shaft which is most constricted, runs rather nearer to the external than to the internal margin, and increases in strength proximally till it becomes $\frac{2}{10}$ inch wide, where the shaft is 3 inches in diameter. All that part of the shaft which is external to the ridge is obliquely flattened, with a slight increase of inflation towards the proximal end, but without the slightest indication of the formation of a proximal trochanter, which presumably was not developed, though the absence of this structure may be due to mutilation. The inner side of the shaft is rather more convex than the outer side; but on its upper side there curves round from where the lateral trochanter should be, a muscular ridge, which is rather stronger but less well defined than the principal median ridge, towards which it very slowly converges proximally. At first the width between the ridges is nearly $1\frac{1}{2}$ inch; but at 3 inches nearer to the proximal end it is narrowed to $1\frac{1}{10}$ inch; and as it narrows, the area thus defined between the muscular ridges, which is at first flat, becomes very markedly concave. Proximally the bone curves inward as though approaching the terminal articular head, and the space external to the inner ridge is fairly well rounded. The proximal half of the posterior aspect of the bone is somewhat crushed, and appears to have been more convex than usual. It may have terminated towards the outer side in a slight ridge, and shows but very slight or uncertain indications of the posterior muscular ridge seen in the second species. The lateral trochanteroid muscular indication is placed a little higher up than is usual with the lateral trochanter; it is about $1\frac{1}{2}$ inch long, slightly elevated and rounded; its proximal end inclines slightly towards the anterior face of the bone. The lateral outline of the bone is here markedly convex.

The distal end of the bone gives no indication of the widening on the outer side of the articulation which is so often met with, since it is flattened and straight externally. Posteriorly there is a moderately deep broad channel inclined a little outward; it was evidently prolonged between the condyles, and shows the outer condyle, as usual, to have been small, while the inner condyle was large. The bone appears to have been quite as much thickened as usual at the distal end, though only the backward curve of the shaft and no part of the articulation itself is preserved. The whole surface of the shaft is remarkable for the longitudinal muscular roughnesses, which are more marked than in any reptile bone that I have ever seen.

Tibia.

A pair of large limb-bones, both 8 inches long, as preserved, but mutilated before fossilization, so that no trace is shown of either proximal or distal articulations, present, however, characters which unmistakably show them to be the tibial bones (Pl. XXXI. fig. 2). The fragments are straight on the inner side. The shaft bends inward a little at the distal end, has a long anterior crest immensely developed forward at the proximal end, and sends out a compressed process on the outer side. The bone measures from back to front at the proximal end $3\frac{6}{8}$ inches, while the middle of the shaft measures $1\frac{6}{8}$ inch, and the distal end $1\frac{1}{4}$ inch. The whole inner surface is remarkably flattened, and, except for the usual distal widening, shows no character that calls for remark. The posterior aspect is badly defined, somewhat flattened towards the distal end, where the bone is rough with muscular markings, and $1\frac{1}{4}$ inch from side to side. The thickness in the middle of the shaft is apparently less, though the bone may be somewhat compressed; and the thickness varies in the two specimens. In length, the posterior outline is slightly concave in the middle of the shaft, and slightly convex in its upper portion, where it is well rounded from side to side. The outer surface of the bone is convex from back to front, and slightly concave in length. It becomes compressed proximally; so that it is divided by an elevated median ridge into two portions—the posterior somewhat flattened and looking obliquely outward and backward, while the anterior half is deeply concave, the concavity resulting from the natural compression of the shaft anteriorly, so as to form an immense patelloid crest something after the pattern of that figured by Leidy as characterizing *Cœlosaurus*. The anterior margin is somewhat sharp, and is defined at the distal end by a slight angular ridge, which above the middle of the shaft extends inward; so that the proximal portion of the anterior outline becomes convex from side to side, though the side-to-side compression increases, and the bone, where fractured, is again increasing in width from side to side, and measures $\frac{1}{2}$ inch. The upper part of the shaft has a subtriangular section, owing to the elevation of the external or fibular ridge. Fibulæ of two sizes occur; but the larger specimen is so small that I have noticed it under the next species.

Cratæomus lepidophorus, Seeley.

In grouping together the remains which are now to be described I have been influenced partly by their anatomical characters, partly by size, and partly by the fact that I have no evidence of the limb-bones of a third species of the same genus to which any of the bones might be referred. The specific distinctness of this smaller Dinosaur will be found well indicated by the characters of the scapula, humerus, femur, and vertebra. The armour is probably undistinguishable from that of the larger species; and at present there is no sufficient ground for saying how much of that already described belonged to *Cratæomus lepidophorus*.

Left Coracoid.

(See Bünzel, pl. iv. fig. 3.)

The left coracoid is very imperfectly preserved, giving no indication of the outline of the bone, no trace, or even indication of direction, of its union with the scapula, and showing the articular surface for the humerus but imperfectly. The bone, however, is perfectly recognizable; it has been figured by Bünzel as the right side of the ilium of *Iguanodon Mantelli*. Since no other example of a

Dinosaurian coracoid occurs in this formation, it may be useful to record the few indications and characters which it displays. The length of the fragment is about $11\frac{1}{2}$ centim.; its breadth is $4\frac{1}{2}$ centim. I infer it to have been a bone, however, fashioned on the plan of the coracoid of *Hylæosaurus* or *Scelidosaurus*. The bone thickened considerably towards the articular surface for the humerus, where the greatest transverse measurement is 36 millim., though, being eroded, this may not have been its widest point. The length of the articulation is about 65 millim.; but, from the state of preservation of the specimen, this can only be given approximately. There are some irregularities on the surface which would suggest cartilaginous covering, such as is indicated by the articular end of the scapula. In length, the surface is slightly concave. Below the articular surface the bone is excavated concavely in length, though the excavation is not very deep. This inferior surface is obliquely compressed on the inner side, so that a slight and rounded ridge extends downward from the articular surface on the outer margin of the bone. The excavation extends slightly under the articular surface. The visceral surface is so eroded as to be almost unrecognizable, only one or two patches of unworn bony surface being preserved. The external aspect towards the scapular articulation is roughened with longitudinal ridges. The middle part of the bone appears to be smooth, but carries a row of seven or eight vascular pits close to the elevated and compressed margin of the humeral articular surface, in front of which is a broad shallow furrow, as though the thumb had been drawn over a plastic substance. This furrow becomes wider as it extends downward, and at its distal termination is margined by slight muscular rugosities. Distant 3 centim. from the upper part of the humeral articulation, and rather more, apparently, from the margin of the scapula, was the coracoid foramen, which was about 15 millim. in length and probably ovate or pear-shaped, though its outline is imperfectly preserved. The external surface of the bone appears to have been convex both in length and breadth. The size of the bone can only be inferred from comparison with allied genera. From its imperfect condition I do not feel assured that this bone may not belong to the larger species.

Right Scapula.

This comparatively small bone, though corresponding in a general way with the larger specimens described (see fig. B, p. 656), presents remarkable differences, which enforce the conviction that it belongs to a very distinct species. The blade of the bone is flat, and presents no curvature of plane; its anterior margin is relatively straighter; the acromion was smaller and differently placed, and approached almost to the margin of the humeral articulation. As in the other species, the surface for union with the coracoid is eroded, though apparently to no great extent; and though the bone is imperfect at the opposite free end, there is no reason to suppose that it extended appreciably beyond the part preserved. The extreme length of the specimen is 18½ centim. The length of the posterior margin to the humeral articulation is about 15 centim., the length of the chord of the arc of the posterior curvature is 13½ centim., and the abscissa is about 28 millim.; so that the curvature is much less than in the large species. The posterior margin is also more inflated; it is similarly sharp at its distal end; but the bone thickens steadily towards the humeral end, where it rapidly expands, chiefly on the inner side, to form the humeral articular surface. The posterior margin is more rounded on the external than on the internal surface, giving the effect of an obscure ridge along the visceral border of this outline of the bone. The anterior border is also well rounded and thicker than the posterior border, the thickness in the middle of the blade being about 12 millim. The outline divides itself into a proximal part, which is concave, and a distal part, which is straight. The middle convexity of the outline is much less pronounced than in the larger species. The concavity towards the proximal end is due to the prolongation forward of the comparatively thin process for union with the coracoid. The middle part of the anterior margin is marked with fine parallel muscular ridges; and from this region the spine of the scapula is prolonged downward obliquely across the bone, so that it terminates at about the middle of the proximal end of the bone, which is 9 centim. wide. The least width of the blade in the middle of the concavity on the anterior side of the margin is less than 5 centim. The width at the origin of the spine of the scapula is about 53 millim.; and the width at the distal end, as preserved, is 6½ centim. The spine is remarkably straight; and even the length to its acromial termination is nearly 10 centim.; it does not so much suggest the form of spine in a mammalian scapula as that of *Hatteria*, existing as a broad rounded ridge, which divides the proximal end of the external surface of the bone into two areas, which are both concave in length, though the outer subtriangular area is rather wider and shallower. The acromial process is imperfectly preserved proximally; and hence the spine appears to terminate in a rounded ridge which is about 2 centim. high and approaches to within a centim. and a half of the humeral articulation. The thickness of the bone from the internal to the external surface at the worn or eroded termination of the spine of the scapula is 4 centim. The width of the process is less than 1½ centim.; and the measurement from its outer border to the anterior coracoid margin is about 5 centim., or over 4 centim. from its inner margin to the posterior humeral articulation. The visceral surface is remarkably flat; but beneath the region occupied by the spine the base was somewhat concave. The humeral articular surface obliquely truncates the inner half of the proximal end. It is much roughened and grooved with the marks of a cartilaginous epiphysis, and was broader in proportion to its length than in the larger species. It shows some sign of crushing, and is fully 4 centim. wide and 47 millim. long. Its posterior outline is much broader than in the larger species; and the axis of the articular surface was not materially different from the plane of the blade. The thickness of the anterior coracoid process was but little more than $1\frac{1}{2}$ centim. where widest, and became somewhat narrower as it extended outward.

Humerus.

Both the right and left humeri are strong bones (Pl. XXIX. figs. 1–3) which, previously to fossilization, had lost both proximal and distal articular ends. They are of exactly the same length as preserved, and are mutilated in almost the same manner, the distal ends especially being obliquely truncated from behind forward; and they show a subquadrate section. The right humerus is slightly the more perfect; and neither bone is distorted by pressure.

The fragments are 8 inches long; and, as preserved, the right humerus is $4\frac{1}{4}$ inches wide at the proximal end; the left humerus is 4 inches wide; the shaft is most constricted in the middle, where it measures $1\frac{7}{10}$ inch from side to side; there is no corresponding constriction from back to front; but in this position the antero-posterior measurement is $1\frac{1}{2}$ inch. The bone widens distally; but, as preserved, the distal measurement from side to side is only $2\frac{3}{10}$ inches. The proximal articular head was nearly in the same plane as the distal end. The inner lateral outline is gently concave; the external outline is deeply concave, owing to the expansion outwards of the large thick deltoid process, which is bent at a considerable angle with the shaft. The antero-inferior and postero-superior outlines are both nearly straight, though very slightly concave; and they converge slightly from behind forward, owing to the slight distal twist giving to the bone an appearance of thickening to that end. At the distal end the shaft becomes flattened both in front and behind; and these surfaces are nearly parallel; and, where fractured, the bone is here $1\frac{6}{10}$ inch thick on the outer side, and somewhat thinner on the inner side. The remainder of the inferior surface is anterior to, and makes a slight angle with, the subtriangular flattened distal area. It also may be said to be a long triangle extending from the inner corner of the distal articulation forward to the divergent elements of the proximal end (fig. 2). Nearly its whole length is straight; and its middle portion is more rugose with muscular attachments than the rest of the bone: the markings have the appearance of slightly impressed ovate pits, which extend for a length of nearly 3 inches. This inferior area is defined by faint lateral ridges, and proximally, beyond the muscular markings, becomes somewhat deeply concave from side to side, and compressed towards the superior aspect, so that in length it is convex. This area is a little inflated on the inner portion, and terminates laterally in a slight sharp ridge. The outer expanded wing has a well-rounded margin.

Superiorly the bone is highly convex from side to side (fig. 1), though somewhat flattened on the inner and posterior side, and also on the expanded external process, which is smooth and slightly concave in length, and slightly convex from within outwards. The upper aspect of the bone is divided into two portions by an oblique moderately elevated muscular ridge, which extends for about $3\frac{1}{2}$ inches across the middle of the shaft from near the inner side proximally towards the outer side distally; and though the whole superior surface, except the expanded crest, is roughened with muscular lines, another fainter ridge may be traced running straight distally from the proximal termination of the oblique ridge. Immediately below the proximal articulation in the middle of the shaft is an elevated muscular boss about $1\frac{1}{10}$ inch in diameter, which, as preserved, is subcircular. The thickness of the shaft at its inner margin is $1\frac{6}{10}$ inch, and at its outer margin $1\frac{3}{10}$ inch. The radial crest thickens towards the proximal surface, and curves a little upward. The outline of the fractured proximal end is somewhat boat-shaped and compressed (fig. 3). This humerus is quite distinct in character from any form of which I have any knowledge.

Femur.

The right femur (Pl. XXXI. fig. 5), found in 1876, is $10\frac{2}{10}$ inches long. The left femur (Pl. XXXI. fig. 4), found in 1877, is hardly more than 10 inches long. This difference is apparently due to the different ways in which the bones are compressed. They are both in the same state of mineralization, of a rich chocolate-brown colour, and quite free from matrix, which has been removed by Professor Suess. The bones belong to a somewhat distinct type; they offer many resemblances, as Professor Suess pointed out to me, to *Cryptosaurus* of the Oxford Clay, but are more slender. They therefore show the typical characters of Dinosaurs, though there is a difference from all English genera in the proximal anterior trochanter not being separated from the shaft; and there is a remarkable development of muscular ridges on the bone, one of which extends on the proximal posterior face (fig. 4) in a curve upward and outward from the small middle trochanter on the inner margin of the shaft to the outer and external margin of the proximal articulation. It is impossible not to recognize the similarity of this strong muscular ridge to the ridge seen on the corresponding aspect of the mammalian femur; and if this coincidence be admitted, it goes far to prove that the middle trochanter, which is the most distinctive mark of the femur of a Dinosaur, is homologous with the inner or lesser trochanter of man; and so far it would seem rather to imply a foreshadowing of a mammalian plan of muscle-arrangement. A similar muscular attachment to this may be observed in Crocodiles above the middle of the shaft. From it an intertrochanteric muscular ridge extends to the position in which the proximal trochanter of Dinosaurs is seen when it is developed. The shaft is most constricted in its distal third, where there is a slight flexure bending the distal articulation backward; both articular ends appear to have been highly cartilaginous, since they are marked with ramifying furrows and occasional pits. As is usual with cartilaginous surfaces, the articular margin is sharply defined.

The proximal articular surface is best preserved in the right femur, and, as usual, consists of a subcircular head (fig. 5), which is directed inward and forward, and a narrower external area. The posterior border of the articulation is nearly straight; but the anterior outline is deeply excavated between the head of the bone and the external trochanter. The globose head measures $1\frac{7}{10}$ inch from front to back; and may be considered to be $1\frac{9}{10}$ inch from within outward; but the entire length of the proximal articular surface was about $3\frac{2}{10}$ inch. The articular surface beyond the head contracts to less than 1 inch from front to back, but widens again to fully $1\frac{3}{10}$ inch at the border of the external trochanter; as in *Cryptosaurus eumerus,* the narrower external part of the articulation is concave from within outward, and does not extend so far proximally as the convex head by half an inch. The length of the bone to the distal border of the head on its inner margin is not more than 9 inches.

The anterior proximal trochanter (fig. 5) is about $1\frac{1}{2}$ inch long, and convex in length; so that it dies away both distally and proximally, where it merges in the articular surface. It is rough with oblique muscular markings, and rounds into the flattened but slightly convex external surface, which is also roughened, with a triangular area of muscle-marking $2\frac{1}{2}$ inches long, which tapers distally. Below this area the external side loses its flattened aspect, and becomes rounded from front to back.

The proximal half of the shaft is considerably compressed from above downward, and is flattened on both aspects: its width from within outward in a line with the distal limit of the proximal trochanter is about $2\frac{4}{10}$ inches, and just above the lateral inner trochanter about $1\frac{7}{10}$ inch, while just below the lateral trochanter the width is about $1\frac{3}{10}$ inch; and there, as the shaft becomes narrower, it grows more convex from side to side. The superior or anterior aspect of the bone is marked with a strong longitudinal muscular ridge, which originates towards the hinder part of the articular ball, curves a little outward and then inward, and extends as nearly as possible in the middle line of the shaft for a length of $6\frac{1}{2}$ inches; it is moderately elevated, strongest proximally, and dies away where a distal flattening of the bone gives an aspect of flexure to the lower part of the shaft. There is also a second muscular ridge, which originates at the same point, below the outer limit of the proximal head, and, running obliquely inward, curves round the convex inner side of the bone and becomes merged in the proximal limit of the trochanter. Both these ridges are less marked than in the larger species.

The posterior aspect of the shaft (fig. 4) is much more flattened. The strong muscular ridge to which I have already referred as defining an area homologous with the obturator-region of mammals, extends distally for nearly 3 inches, and then curves more sharply inward to merge in the inner trochanter. From this ridge extend obliquely inward, so as to cross each other, two series of narrow straight linear muscular markings. Parallel to the sigmoid curve of the proximal articular margin, and about a quarter of an inch below it, is a line of about six or eight circular vascular perforations.

The lateral trochanter is placed, as usual, at the angle between the internal and posterior aspects of the bone (fig. 4). It is moderately elevated, about $1\frac{1}{2}$ inch long, $\frac{6}{10}$ inch wide proximally, and tapers distally; it is placed exactly midway between the proximal and distal articular ends. Below the trochanter the section of the shaft becomes subtriangular, being flattened on the internal aspect and posteriorly, and rounded on the external and anterior aspect.

The distal articulation is chiefly noticeable for the inflated expansion of the bone at the external margin, and for the relatively large size of the condyles (fig. 4). The articular surface is 3 inches long in the left femur, which has this region best preserved; it is very moderately convex from behind forward, and very slightly concave from within outward, and rounds gently into the anterior surface of the bone, where a concave natural impression divides the anterior margin into a larger internal area and a smaller area which is external. There is the usual ill-defined gently concave pit for ligamentous attachment just above the articulation on the flattened internal surface of the bone, which looks obliquely upward, much as in *Cryptosaurus*. The internal condyle is the larger of the two; it is about an inch wide, and curves round considerably on the posterior aspect of the bone, so as to cause the articulation to measure $2\frac{2}{10}$ inches from front to back. The interspace between the condyles is about $\frac{8}{10}$ inch; and in this region the articulation measures, from front to back, $1\frac{1}{2}$ inch. This depression becomes prolonged up the middle of the posterior side of the shaft towards the inner part for about $1\frac{1}{2}$ inch. The smaller condyle is more compressed, about $\frac{6}{10}$ inch wide, and gives an antero-posterior measurement to the articular end of 2 inches; and external to this condyle is a concave area or groove, $\frac{1}{2}$ an inch wide, which defines it from the well-rounded broad external margin. The small part of the articulation external to this condyle makes a considerable angle with the major part of the surface. The anterior half of the articular surface is nearly smooth; but the posterior half is deeply scored with about eight comparatively straight grooves, six of which lie between the condyles. These grooves appear, from their corresponding development at the anterior part of the proximal articulation, to be in the positions of greatest pressure and greatest condylar growth, and may be regarded as evidence that the bone was carried in an oblique position, as among mammals.

Tibia.

A smaller pair of tibial bones are much less perfectly preserved than those of the large species, only exhibiting about $6\frac{1}{4}$ inches of the middle of the shaft (Pl. XXVII. fig. 19). Their ends are decayed in the usual way; and distally the fractured outline was subtriangular, but formed a triangle in which the anterior and two converging posterior elements rounded into each other, and were subequal. Here the extreme antero-posterior measurement is about $1\frac{2}{10}$ inch, and the extreme width from side to side at the distal end is the same. In the middle of the shaft the antero-posterior measurement remains unaltered, but the side-to-side measurement is reduced to $\frac{19}{20}$ inch; where the specimen is fractured proximally, the antero-posterior measurement is $\frac{17}{20}$ inch, while the measurement from side to side in the middle of the shaft is $1\frac{1}{10}$ inch. The right tibia (fig. 19) does not appear to be crushed; but the left specimen is somewhat fractured at its distal end. The inner side in both is flattened, though not quite so flat as in the larger species. The outer side is convex, but divided into two portions by a median ridge, which in its upper $3\frac{1}{2}$ inches is strongly muscular, though the markings appear to be stronger on the left tibia than on the right—a condition the reverse of that which obtains in the larger species. The muscular ridge is made up of three or four close parallel ridges. The posterior half of this side of the bone appears to be more flattened than in the larger species, while the anterior half shows indications of a similar longitudinal concavity, though the specimens are fractured too low down for more than the beginning of it to be detected. The proximal fracture displays a triangular outline with a long straight base formed by the inner side and two shorter converging sides which form the outer side. Here the bone is less than twice as deep as it is wide. On the posterior side, as compared with the larger species, the side-to-side compression is greater towards both the proximal and distal ends, while anteriorly the bone is rather more rounded from side to side. There is about as much difference in size between the two types of tibiæ as there is between the two kinds of femora, though, so far as can be judged from the fragments preserved, the differences in essential characters in the tibiæ were less important than those of the femora.

There have also been found fragments of patelloid ridges of tibiæ which appear to belong to a species slightly larger than either of these; but the materials are too imperfect for description, or even for absolutely certain osteological identification.

Fibula.

The specimen which Bünzel (pl. iii. f. 12, 13) regarded as the upper half of the left humerus of a Crocodile is undoubtedly a somewhat obscure fossil. It, however, presents nothing in common with any crocodilian humerus with which I am acquainted, especially differing in its remarkable compression, in wanting all trace of a radial crest, in the lateral compression of the shaft at right angles to the supposed head of the bone, and in the inflation of the inferior side of the head. While, therefore, I have no hesitation in affirming that the specimen is not crocodilian and not a humerus, the loss of the terminal articular end and the evidence of a certain amount of crushing makes any other determination a matter requiring some caution. The contour, however, of the bone is so similar to that of the tibia of *Cratæomus*, and one aspect, and especially the posterior margin, is so roughened with muscular attachments, that I have little hesitation in affirming that we have here the fibula of one of the Dinosaurs—a view which is further supported by the circumstance that the tibia has a strong ligamentous ridge that would correspond to the rough side of the fibula. Moreover I have found a further small portion of the supposed shaft, not absolutely continuous, but showing that the bone retained the same characters for some length further, and did not expand at its distal end. It therefore may be well to state that this specimen (Pl. XXVII. fig. 20) is to be regarded as a right fibula imperfect at the proximal end, but, as preserved, $4\frac{1}{2}$ centim. wide. As preserved, the main piece of bone is over 10 centim. long, and, with the additional fragment and the lost interspace, would indicate a length of about 14 centim. The distal end is imperfect, having decomposed before fossilization. The anterior margin is concave, the posterior margin straight and rugose. The thickness of the proximal end, as preserved, is about a centimetre, while the fractured distal end is 7 millim. thick and about 17 millim. wide. As remarked by Bünzel, the distal fracture is semiovate, but the flattened side is towards the transversely convex head of the bone, while the convex distal outline is towards the transversely concave or external surface of the head. Other fragments of similar character, also presumably fibular, but too imperfect for detailed description, may be referred, one to a larger and one to a smaller Dinosaur.

Metatarsal Bone.

(See Bünzel, pl. iv. figs. 11, 12.)

The specimen regarded by Bünzel (t. iv. f. 11, 12) as the phalange of a Crocodile is almost too imperfect for accurate determination; but since it is certainly either the second or third metatarsal of a Dinosaur, probably the former, it requires a slight notice. As preserved, it is little more than $6\frac{1}{2}$ centim. long and about 3 centim. wide in front. What I take to be the inferior surface is the best preserved; only a small portion remains of the anterior articular end, which was unusually convex from above downward. The lateral outlines are concave; and the bone measures only 2 centim. from side to side in the middle, where most constricted. The superior surface was compressed, so as to form an obscure broad rounded ridge on the outer side, with a very slight broad channel below it on the inner side. The depth of the bone in the middle of the shaft is $2\frac{1}{2}$ centim. The under surface is concave in length, flattened from side to side, with a slight twist in the plane, which is directed a little inward as it extends forward. The posterior fractured end is subtriangular, owing to the flattening of the base.

Claw-Phalange.

(See Bünzel, pl. iv. figs. 4, 5.)

A claw-phalange (Pl. XXIX. fig. 6), probably pertaining to the second or third digit of the left hind limb, as indicated by Bünzel, is ascribed by that writer to a species of *Scelidosaurus,* but may be referred to *Cratæomus lepidophorus.* It is 33 millim. long, 25 millim. wide behind, and 22 millim. wide in front, is compressed from above downward, and, though blunt anteriorly, is most compressed on the right border. The articular surface is imperfectly preserved, but was concave from above downward, straight transversely, and inclined obliquely to both superior and inferior aspects. The superior surface, which is slightly convex from side to side, is margined on each side by a strong groove, which is not very deep, and extends forward for more than half the length of the bone. Between these grooves are a number of slight parallel ridges. At the sides the bone is excavated for the attachment of powerful ligaments, more so on the left side than on the right; and on the left side the irregular excavations extend further forward. The under surface is comparatively flat, but concave in length, convex from side to side, and marked in the middle with two irregular longitudinal grooves, which have a tendency to branch as they pass forward. These grooves are very imperfectly indicated in Bünzel's figure, which gives no indication of their dendroid character. The posterior outline of the bone is ovate, and less than 2 centim. deep.

Dorsal Vertebra.

(See Bünzel, pl. i. figs. 24, 25.)

A dorsal vertebra with the neural arch fairly well preserved is the best vertebral evidence of this species (Pl. XXX. fig. 5). The centrum is 4 centim. long, flattened on the under side, where it is $1\frac{1}{2}$ centim. broad in the middle, where most constricted; it is concave from front to back. The sides are compressed and somewhat concavely excavated below the neural arch, where the least transverse width is $1\frac{1}{2}$ centim. Thus the body of the vertebra in section would be subquadrate. The anterior articular surface of the centrum is concave, 32 millim. broad, and 27 millim. deep. The posterior end is not concave, but somewhat flattened and convex from above downward. The margin is a little worn; the greatest transverse width is less than 3 centim., the greatest depth $2\frac{1}{2}$ centim. The neural arch is high, though not unusually so for a Dinosaur. Its base is nearly as wide as the anterior face of the centrum. It extends the whole length of the centrum, and has the aspect of being compressed from side to side below the transverse processes. The borders of the neural arch are excavated (fig. 5), moderately in front, and more deeply behind, to form the intervertebral passage for the nerves. The least length of the neural arch from front to back, in the middle of the neural canal, is 23 millim. The length from the anterior to the posterior zygapophyses is about $5\frac{1}{2}$ centim.: and the upper border of those facets is fully that height from the base of the centrum. The anterior zygapophyses are directed upward, forward, and inward. Their external surface is rounded. There is a V-shaped notch between them in front; and they form the anterior border of a transverse cup-shaped depression in front of the neural spine, the hinder borders of which cup are contributed to by the transverse processes, which are directed upward and outward, and placed between the zygapophyses in the middle region of the vertebra. The neural spine is narrow and short, and placed on the hinder half of the neural arch; only its base is preserved. The posterior zygapophyses are circular facets placed below and somewhat beyond its hinder termination. They converge downward, but are separated by a broad groove. The height of the vertebra to the base of the neural spine, as preserved, is $6\frac{1}{4}$ centim. The extreme width over the posterior zygapophyses is $2\frac{1}{4}$ centim. The width of the groove between them is about $\frac{1}{2}$ centim. The side of the neural arch is of the usual character, with ridges ascending from the anterior and posterior ends of the arch which converge upward; and the posterior ridge, which is the better marked, passes into the strong ridge which extends under the base of the transverse process (broken away on the left side) The area between these two lateral ridges, which is unusually deep and narrow and ill-defined, appears to be the capitular articulation for the rib. The space posterior to the lateral ridges is concavely excavated. The transverse process is broken off short. I infer this to have been an early dorsal vertebra. The posterior convexity of the centrum shows it to have been full-grown. This, no less than the long narrow articulation at the side, and the other characters of the neural arch described, show it to indicate a distinct species from the vertebræ referred to *Cratæomus Pawlowitschii.*

Megalosaurus pannoniensis, Seeley.

There are two teeth of a carnivorous Dinosaur (Pl. XXVII. figs. 21–23) which present some resemblance to the teeth of *Megalosaurus* and *Lælaps*, differing in no character of importance except size, the fineness of the serrations, and shortness and breadth of the crown. One specimen is a crown tolerably perfect, fractured just above the base and before the commencement of the fang (fig. 21). The other is the lower half of the crown of a somewhat larger but similar tooth. The more perfect specimen is 21 millim. long, curved backwards, quite straight, convex on both sides, though rather more so on the inner side, and with the inflation towards the convex anterior margin of the tooth. The posterior margin is relatively straight, but is concave. The surface of the tooth is marked with microscopic longitudinal wrinkling and faint parallel transverse lines of growth, only to be detected by the way in which they reflect light. The posterior margin throughout its length is marked with perfectly regular transverse serrations, which extend along the tooth like a fringe. Towards the extremity of the crown the serrations become slightly shorter. On the anterior border (fig. 22) the serrations are of a similar character, but only reach down the tooth for 13 millimetres, becoming smaller as they disappear. There are about forty-five of these minute chisel-like serrations in all this margin. Where they terminate, the tooth is just appreciably narrower and the anterior margin is rounded, so that the transverse section (fig. 23) is exactly the same as in *Megalosaurus.* The serrations of the posterior margin are larger than those of the anterior margin; so that there are only about forty in the entire length of the tooth. The antero-posterior measurement is over a centimetre, and the thickness 6 millimetres. There are no bones that I could refer to this species; and when they are discovered the teeth may prove to belong to an animal as different from *Megalosaurus* as is *Lælaps*.

Ornithomerus gracilis, Seeley.

The specimen figured by Bünzel, pl. vii. figs. 22, 23, and regarded (p. 15) as the middle of the dorsal rib of a lizard, is the distal half of the shaft of the femur of a remarkable new Dinosaurian. From the circumstance that Bünzel has figured the external instead of the internal aspect of the bone, it would have been difficult to make this interpretation without examination of the specimen. The fragment (Pl. XXVIII. figs. 6, 7) is only $5\frac{1}{2}$ centim. long, has a nearly circular shaft 13 millim. in diameter at the proximal fracture, becoming a little more compressed distally from above downwards and slightly more expanded from side to side. The specimen shows no trace of the distal articular end; but distally the bone is a little flattened on the inferior and posterior surface, and slightly compressed towards the outer border. There is a distal curve in the bone, rather more marked, perhaps, than in the crocodilian femur. Towards the proximal end of the fragment the transverse fracture passes through a longitudinal muscular pit, margined below by an elevated muscular ridge, which is prolonged further distally than the muscular pit, and appears to have terminated in a free process, though the extremity of this is broken away. This is the internal trochanter of the Dinosaurian femur (figs. 6, 7). What remains of the muscular impression is about 12 millim. long and half a centimetre wide. What remains of the sharp ridge bordering it is 17 millim. long. I am not acquainted with any Dinosaur in which the femur has this cylindrical bird-like form. The shaft is formed of dense bone with a large medullary cavity about 7 millimetres in diameter (fig. 7), and has, at first sight, rather the aspect of the bone of a bird than of a Dinosaur. Though the fragment is so imperfect, it is so characteristic that I have ventured to refer it to a new genus.

Doratodon carcharidens (Bünzel).

The sculpturing of the outer surface of the jaw, no less than its general form, would seem to have weighed with Bünzel in referring the specimen represented in his plate i. figs. 29–32 to the genus *Crocodilus*. I find myself unable, however, to accept this generic determination, partly because the teeth are such as indicate a different genus, and partly because I am led to refer the maxillary bone represented in the same plate, figs. 3–5, to the same genus and probably the same species as the lower jaw; and this shows, though the fragment is very imperfect, characters which are not met with in the genus *Crocodilus*. But whether its affinities are stronger with Crocodiles or with Dinosaurs is a matter far from easy to determine. The lower jaw consists of slender rami, having a length, as preserved, of about $13\frac{1}{4}$ centim. without reaching back to the articular region. The jaws converge forward to the symphysis, where the contraction ceases, and there is a slight anterior expansion before the lanceolate anterior termination. The greatest width of this slight expansion is 2½ centim.; and the width of the diverging rami at 10 or 11 centim. from the anterior termination is over 5 centim.; thus the jaw is remarkably pointed. The lateral contour of the alveolar margin is convex from before backwards in the region of the symphysis and concave in length behind the symphysis. The symphysis is 3 centimetres long, and is made up in the anterior and inferior part by the dentary bone, and in the posterior and superior part by the opercular bone, which, on the alveolar aspect, forms half the symphysis, while inferiorly it only constitutes the hinder fifth. In Crocodiles the opercular bone does not enter into the symphysis. The anterior part of the jaw in the symphysial region is excavated in a spoon-shape, owing to the remarkable and vertical elevation of the alveolar margin, an elevation which appears to have relation to the straightness and vertical position of the teeth; so that the fangs could not have made an angle with the crown. The whole inner side of the ramus is formed, as in crocodiles, by the opercular bone, which, as Bünzel remarks, is smooth and slightly rounded at its inferior and superior margins, and extends back beyond the alveoli, only showing in its anterior part two or three nutritive foramina. The external surface of the bone is formed of the dentary element, except, it may be, towards the hinder superior border, where a suture appears to indicate on the inner side a coronoid bone. On the under surface the jaw is flattened at the symphysis, but the flattened area rounds up anteriorly to the alveolar margin; but where the rami begin to diverge, there is a distinct sharp angle between the base of the jaw and its side, and this ridge is prolonged backwards for a large part of the region through which the teeth extend: and here the base of the ramus is slightly convex from side to side till, with the fading of the angle into the upper surface, it becomes more rounded and narrower. The suture for the opercular bone runs along the inner third of the base. In ornament, the anterior expanded end of the snout is pitted much after the pattern of crocodiles, and evidently with similar relation to a vascular condition: but inferiorly the ramus is marked with rough, short, irregular longitudinal ridges, which extend round onto the side but do not rise to the alveolar region, which is comparatively smooth and marked with a row of relatively large foramina, about seven or eight in number, and placed above the middle of the lateral margin in a concave line or groove. As they extend backwards they rise nearer to the alveolar margin, and form the basis of a slight compression of the bone above them. Posterior to the symphysis the depth of the jaw increases: it is about 9 millim. in front, 17 millim. at the last tooth-socket, and 3 centim. in the coronoid region; so that it increases in depth more rapidly behind the teeth. It is difficult to count the exact number of sockets; for some of the fangs are preserved, and in other cases the teeth have fallen out: but there were not fewer than fifteen; and as the alveolar groove is carried back and becomes very shallow beyond this point, it is possible there may have been five teeth more, of small size, in the hinder part of the jaw, making a total of twenty. The teeth are largest in the middle of the jaw; but only the tenth on the right side has the crown preserved *in situ*. The crown is 8 millim. high, and nearly 6 millim. wide at its base. It is triangular in lateral outline, is curved inwards and directed upwards, inwards, and backwards. Its base is rather less than 3 millim. thick. Each surface is convex, terminating in a sharp cutting-edge, which is very finely serrated along the margin. In front and behind there is a constriction, so as to separate the sides of the crown from the elliptical fang; but this constriction is not appreciable on the interior or the exterior aspect of the tooth. This form of tooth is entirely Dinosaurian. Four teeth have been found separately which show the same character. Two of these are crowns broken off directly from the fang, and show the constricted oval base of the crown where the lateral ridges become pinched in. These teeth are sharply pointed, and have the surface smooth to the naked eye. There are also two teeth which have the same general form, except that the crown is broader and shorter; and, owing to this circumstance, the serrations, which are transverse to the cutting-edge, have an appearance of being directed obliquely upward. These, however, are probably successional teeth, it may be from another part of the jaw, or from the upper jaw. A certain amount of variation is obvious, because the fang of the eleventh tooth on the left side shows that the base of the crown was marked with blunt parallel ridges.

There is a fragment of the anterior end of a right dentary bone from which the opercular element has come away, and which clearly belongs to the same genus. It may indicate another and smaller species, since the rami appear to diverge more rapidly, to have contained more numerous teeth, with smaller and more circular fangs, to want the anterior elevation of the jaw in its presymphysial region, to be devoid of the ridge between the base of the jaw and the side, and to have the side convexly inflated instead of flattened, especially external to the alveolar margin. The ornament also appears to be slightly different; but as no teeth are preserved I have not thought it necessary to give a name to this fragment. The length of the dentary symphysis is 1½ centimetre, and the length of the fragment 4½ centimetres. The corresponding length of the dentary symphysis in the larger specimen exceeds 2½ centimetres.

The fragment of upper jaw briefly described by Bünzel, p. 6, pl. i. figs. 3–5, I have, as already mentioned, identified with the lower jaw of the large species just described. Notwithstanding the circumstance that Bünzel remarks on its close resemblance to existing crocodiles, he places the nasal aperture immediately in front of the orbit, which alone would suffice to show that the type differed from crocodiles fundamentally. In fact, the perforation of orbit and nares in the maxillary bone would be a modification of old-fashioned anatomy of no ordinary kind, since the maxillary bone does not enter into either the orbit or the anterior nares of the crocodile, and it certainly does not enter in any known Dinosaur into the external wall of either of these vacuities. Agreeing with Bünzel, that the margin which he regards as the anterior border of the orbit is correctly identified, I regard the perforation which he terms nasal as the preorbital vacuity characteristic of Teleosaurs, and more or less developed in various Dinosaurs. The bone between the orbit and the preorbital vacuity is always the lachrymal; and I therefore identify the lachrymal bone as united by suture with the maxillary. The length of its base is 2 centim.; but it is fractured superiorly, and therefore its outline cannot be stated, further than that it appears to have been triangular. The posterior margin is concave, rounded and thickened, with an indication of a groove, which may have had relation to the lachrymal canal. The surface is sculptured with somewhat oblique ridges, which are short and irregular, and deeper than the sculpturing on the maxillary. The suture with the maxillary is straight but slightly oblique, so that it laps a little further down on the inner than on the external surface. The preorbital vacuity only shows a small portion of its basal margin, which is rounded. The lachrymal bone in front of it is thin, and gives the aspect of the vacuity having penetrated obliquely inwards and forwards. A small portion is preserved of a suture on the superior surface, which is straight and parallel to the alveolar surface, or but slightly inclined forwards. Hence it may reasonably be identified as the suture for the nasal bone. The depth of the bone from the nasal suture to the alveolar border is 22 millim. Anteriorly the bone is fractured, so that there is no indication either of its length or of the length of the nasal suture, or of the nature of its relation to the premaxillary bone. The posterior end is also fractured; but just below the orbital border there is a minute indication of a suture, evidently indicating the malar bone, and showing that its relations were the same as in Dinosaurs. The surface of the maxillary bone is marked with an indefinite rough sculpturing, which, in the upper part, has a tendency to assume a linear character; and the hinder part is somewhat lightly pitted. The internal surface is necessarily irregular; and its appearances may be passed over in so far as they relate to the region above the palate; but above the alveoli the bone evidently developed a horizontal palatal plate, which has been almost entirely broken away. It appears to have been notched out posteriorly into a postmaxillary vacuity, such as is seen in the crocodile, since the hindermost 1½ centimetre is a smooth, sharp, somewhat concave margin bordering the alveoli.

It is very difficult to understand the alveolar structure from an inspection of Bünzel's plate, since it gives the appearance of a double row of tooth-sockets: this is due to the circumstance that while the tooth-sockets (in which most of the teeth still remain) are placed close to the outermost alveolar border, there is, internal to them, a parallel series of pits which are broad and shallow, and are, I think, produced by the circumstance that the teeth of the lower jaw were received scissor-like between the teeth of the upper jaw; and these pits I regard as excavations which have resulted from the pressure of their crowns—a view which is especially supported by the circumstance that they are deeper posteriorly, where the palatal border is but little above the outer alveolar border, and are less marked anteriorly, where the palatal border rises about 8 millim. above the alveolar border. The teeth extend along the whole alveolar length, which is $4\frac{1}{2}$ centim., and were eight in number in the fragment. They are larger in front than behind, and mostly appear to have been successional teeth not fully cut. The first, where broken, is 7 millim. long and 4 millim. thick. The second is less than 4 millim. long, and is clearly a section of the fang; but one of the later teeth shows the sharp serrated cutting-edge, compressed form, and smooth enamel characteristic of the teeth of the lower jaw; and it is on this evidence that I have felt justified in referring it to the same species. Both fang and crown appear to have been hollow; but as the cavities are filled with iron pyrites, I have not been able to excavate them.

There are a few other unimportant fragments, chiefly of the lower jaw, which exhibit similar sculpture, and presumably belong to this genus, but too imperfect to be worthy of description.

There is a small claw-phalange (Pl. XXVII. fig. 26) which, perhaps, for the present may be noticed here, seeing that it is quite impossible to say with certainty to which of the animals it belonged. It is 17 millim. long, curved downward and to the right. It tapers to a point, and is subtriangular, being flattened on the under side, on the left side, and obliquely on the right side, which is large. But these three surfaces round into each other, except where they are divided by the sharp lateral ridges which margin the base. The articulation is 7 millim. deep, a little narrower, concave from above downwards, and convex from side to side.

Rhadinosaurus alcimus, Seeley.

I found this genus upon the femora, which are quite distinct from any thing hitherto discovered. The humeri are such as would be associated with those bones, though there is no proof beyond similarity of character that they belong to the same species. The same remark applies to the vertebræ, which are such as might be expected in an animal of this kind; but there is no evidence of natural association. I have placed this genus next in succession to *Doratodon*, because that genus is founded upon a head, while this is formed for limb-bones; and though there is no evidence to justify their being thrown together, there is a possibility that *Doratodon* belongs to one of the animals of which the head cannot be identified.

Humerus.

Two specimens of humeral bones (Pl. XXXI. figs. 8–10) exhibit characters indicative of an animal in many respects unlike any other in the deposit, especially in the slenderness of the shaft and relatively small size of the articular ends, as well as in the circumstance that the articular extremities were at right angles to each other. Unfortunately both proximal and distal ends are lost by decomposition. The left humerus is best preserved proximally, while the right humerus extends further distally. The length indicated by the two bones without reaching the articular ends is 14 centim.; so that the entire length of the bone, when perfect, was at least 2 centim. more. The left fragment (fig. 8) is fully 12 centim. long, and, when placed with the distal end uppermost, shows a slight convexity on one lateral margin and a corresponding concavity on the other, the concavity facing the anterior and inferior aspect of the bone, the convexity being superior. Owing to the circumstance that the proximal end is absolutely at right angles to the distal end, it happens that the shaft of the bone widens distally. The transverse measurement at the base of the radial crest (fig. 9) is $1\frac{1}{2}$ centim., and at the distal fracture 23 millim. (fig. 10); and it is still widening.

The superior distal surface is convex from side to side, with a slight ridge towards the radial side of the bone, which is really a prolongation of the muscular ridge of the radial crest, which in crocodiles never extends along the superior aspect of the bone. This ridge produces a flattened radial aspect, a slight approximation to which may be observed at the distal articular end of the crocodilian humerus; but here it gives a somewhat compressed and sharp aspect to the inferior radial margin of the bone along the distal half of the shaft, while the ulnar side is relatively flattened or rounded. The bone is marked, on the superior aspect especially, with strong longitudinal striæ or slightly elevated ridges. Its thickness at the distal end, as preserved, is about 13 millim.; but the right bone is a trifle stouter. The inferior aspect is flattened distally with a slight longitudinal depression. The proximal end of the bone necessarily widens, while the shaft remains comparatively uniform. The superior surface is smooth, and convex from side to side, but slightly channelled towards the expanded radial process, which is necessarily placed on the middle of the aspect which, when viewing the distal end, would be regarded as superior. The width of the proximal end appears to have been small. The lower part of the radial crest gives a transverse width, as preserved, of less than $2\frac{1}{2}$ centim. The inferior aspect of the proximal end is longitudinally channelled, and thus divided into a compressed anterior process and a rounded and somewhat inflated inferior and posterior part. The thickness of the bone here at the fracture is just over a centimetre. The whole inferior surface, not only of the radial crest but of the adjacent region of the bone, is roughened with powerful muscular attachments. The right fragment substantially repeats these characters; only the bone is appreciably stronger, with its muscular ridges more marked, and in length shows a decided sigmoid curve, like that which marks the humerus of a crocodile. I am led to refer these bones to the same species as is indicated by the femora next described. In this case they would indicate an animal with remarkably small anterior limbs, suggesting the proportions of a Teleosaur. I may state that this identification is founded chiefly on similarity of general aspect, superficial texture, condition of preservation, and colour.

Femur.

(See Bünzel, pl. iii. fig. 1.)

A pair of remarkable slender bones, somewhat crushed, and without trace of an articular end, which, at first sight, have the aspect of being portions of ribs, I am disposed to regard as the femora of a small Dinosaur, having probably Teleosaurian affinities. Yet such an identification is necessarily somewhat conjectural; and I would therefore state that I am led to the conclusion that the bones are femora (Pl. XXXI. figs. 6, 7) by their slightly curved form, by the widening of what I take to be the proximal end, by the slightly smaller size of what would be the distal end, but chiefly by a large somewhat oblique muscular scar with an elevated border in its lower part, which is situate in the same position as the middle trochanter on the femur of a Dinosaur, which also looks inwards, backwards, and downwards. And I do not recognize so many probabilities in favour of any other interpretation, especially as only two bones have been found, which are right and left, while nearly all the other limb-bones are similarly represented by pairs. The longer specimen measures about 6 inches; it is $1\frac{3}{10}$ inch wide proximally; and the trochanteroid scar reaches to within $1\frac{1}{2}$ inch of the proximal end. At its upper limit the bone is $1\frac{1}{8}$ inch wide. The scar is $1\frac{7}{10}$ inch long, and about $\frac{8}{10}$ inch wide in its greatest width in the middle (fig. 6). It causes the bone to swell out in thickness, so that the internal border is much thicker than the external border, which appears to be somewhat compressed, and which is slightly convex in length; while the inner border of the bone, but for the trochanteroid bulge in its lower part, would be slightly concave. As it is, it is divided into two concavities. The widening of the bone at the proximal end I take to indicate the base of the proximal articulation. The specimen is there slightly incrusted with pyrites; but no trace is preserved of either articular head or external trochanter. The long oval of the lateral trochanter is defined by a ring, which is slightly elevated in its proximal and internal part, and much more elevated on its distal and anterior portion, which gives a width to the bone of $1\frac{3}{20}$ inch, while the width at the distal end is $\frac{19}{20}$ inch. The thickness of the bone at the distal end may be slightly diminished by accidental compression. It is $\frac{11}{20}$ inch on the inner side, which is less than the thickness at the proximal end (fig. 7), where, in a corresponding position, the bone measures $\frac{13}{20}$ inch. The inner border, both proximally and distally, is convexly rounded; the external border appears to be flattened obliquely externally in the distal half, and compressed and rounded proximally. But as the specimen is crushed, this point remains obscure. These femora are among the most remarkable bones that the Gosau formation has yielded.

Dorsal Vertebra.

There are two dorsal vertebræ, both a little crushed and without the neural arches, which belong to such a Dinosaur. From the more perfect of these I draw the following characters. The centrum is $4\frac{1}{2}$ centim. long, with the articular ends flat, and about $2\frac{1}{4}$ centim. wide. The anterior face appears to be rather the flatter and larger; but both articular margins are a little injured by fracture. Their edges are defined by a narrow bevelled area; the body of the centrum is smooth, regularly constricted, so as to be concave from back to front in every position below the neural arch, and devoid of ridges. It is more constricted at the base of the neural arch than elsewhere, and, except in being much more slender and less deep, recalls the dorsal vertebræ of *Anoplosaurus.* The neural canal is similarly narrow.

Oligosaurus adelus, Seeley.
(See Bünzel, pl. vi. figs. 14, 15, pl. vii. figs. 1–4.)

The bone which Bünzel figures (pl. vi. figs. 14, 15) and regards as the right humerus of a lizard, I regard as the right scapula probably of a Dinosaur; while the specimens (pl. vii. figs. 1, 2, and 3, 4) regarded as right femur and fragment of humerus of lizard, I regard, from their correspondence in character and size, as probably referable to the same animal, though the femur entirely wants the trochanter which is usually seen in Dinosaurs. Taken by themselves, these two bones have enough in common with lizards to account for Bünzel's determination; but if the scapula is rightly associated with them, there can, I think, be no doubt concerning their Dinosaurian affinities.

Scapula.

The scapula is a slender compressed bone $4\frac{1}{3}$ centim. long, and imperfect at both ends, but not so much injured as materially to affect its characters. The inner or visceral side is slightly concave in length, and makes no approximation to the concave form the bone has in the crocodile. This inner surface is gently convex from side to side. The posterior margin is nearly straight, becoming slightly concave towards the proximal end. In adopting this nomenclature I have followed the crocodilian analogies rather than those of certain Dinosaurs. This posterior margin, as preserved, is 33 millim. long; it is rounded, rather compressed towards the free end, and somewhat obliquely flattened towards the proximal end, where a slight ridge becomes developed, which extends towards the articulation, giving the bone a thickness of about $\frac{1}{2}$ centim. The blade of the scapula is moderately concave on its anterior border, which, as preserved, is 3 centim. long. The width of the distal end is 11 or 12 millim; in the middle the blade becomes constricted to a width of 1 centim., and then expands proximally. The proximal width cannot be given, on account of fracture; but the specimen, as preserved, is 17 millim. wide. The anterior margin is more compressed than the posterior margin. There is an indication of a ridge towards the proximal end, similar to that on the opposite side of the bone; and between these ridges, which are 13 millim. apart, the proximal end of the bone is concave from side to side. The bone does not greatly thicken at the proximal end, the greatest thickness towards the anterior border is 6 millim. There is a general resemblance in character to the scapula attributed by Professor Owen to *Iguanodon Mantelli* (Pal. Soc. 1854, pl. xiv. fig. 1); but in this form the blade is not so constricted, and it may be doubted whether the anterior process there so marked attained any corresponding development in this fossil; nor is the resemblance closer to *Scelidosaurus*; and, indeed, in the straightness of its posterior margin the bone rather suggests the scapula of an *Ichthyosaurus*, in which, however, the straight margin is anterior.

Humerus.

The bone which Bünzel identifies as belonging to the right side of the body seems to me to be referable to the left side. The reason for this determination is that the articular head of the bone is on the right side, as proved by the thickening, and the radial crest on the left side. Like most of the other specimens, this is imperfect at both the articular ends, though enough remains to convey an idea of the form and length of the bone before it was mutilated. The shaft, which is greatly expanded proximally, is 5 centim. long. The distal end has the superior and inferior surfaces parallel; and the bone is 8 millim. thick and nearly 12 millim. wide, more rounded on the anterior than on the posterior border. From the superior outer border a faint rounded ridge extends up the shaft towards the middle of the articular head; and an impression occurs in its upper half which appears to be muscular. The width of the bone at the proximal end, just above this ridge, is 22 millim. Internal to the ridge the bone is compressed, so as to contribute to form the articular head. External to the ridge it is transversely expanded, somewhat flattened, and marked with strong longitudinal grooves at the outer extremity of the radial border. The radial border is more concave than the ulnar border. The thickness of the radial expansion is about 6 millim., but diminishes proximally. The thickness of the base of the proximal articulation where fractured is about 9 millim. The inferior surface is regularly concave from side to side at the proximal end, and convex in length, corresponding to the transverse convexity and longitudinal concavity of the superior surface. The shaft where most constricted, in its lower third, is less than 1 centim. wide, while its thickness steadily diminishes from the distal end to the radial margin at the proximal end. This bone possesses none of the typical characters of a lizard-humerus, but all those which are usually found in Dinosaurs, though I am unable to name any genus in which the form of this bone is so closely paralleled as to suggest generic identity or even affinity. The distal fracture, which is transverse, is so irregular as to suggest an epiphysial surface from which the epiphysis has come away.

Femur.

Bünzel, though referring this specimen to the right side of the body, has given no indication as to its proximal and distal ends. These determinations are a matter of some difficulty; but it is well known that, as a rule, a Dinosaurian femur is thicker on the inner than on the external margin, which is commonly compressed: and there is usually a certain compression of the bone on the posterior surface. I have hence been led to regard this specimen as probably the shaft of a left femur which has lost both the proximal and distal ends. The fragment is 6 centim. long; the shaft is curved more after the crocodilian than the Dinosaurian pattern; only it is a simple convex curve, without any trace of a sigmoid flexure. The shaft is nearly cylindrical, 1 centim. in diameter in the middle, where most constricted; and there it is about 9 millim. thick. What I take to be the distal end expands transversely to 13 millim., is flattened on the superior and inner borders, flat or concave on the inferior border, somewhat compressed towards the external side. The bone is 9 millim. thick on the inner margin, and 6 millim. thick on the outer margin. Proximally there is a nearly similar expansion of the bone; only the inner border is directed well inwards, the external border is more flattened, and the inferior surface is flattened. The width of the proximal end, as preserved, is $1\frac{1}{2}$ centim. It is impossible, in the absence of more distinctive characters, to form any opinion as to the affinities of this specimen. A curious circumstance concerning it is that, while indubitably a left femur, either end could be regarded as proximal.

Vertebræ.

Two vertebræ are figured by Bünzel, pl. viii. figs. 2–4, which he regarded as indicating a fœtal Dinosaur. It is difficult to discover any evidences that would enable one to confirm this remarkable speculation. The vertebræ are beyond all doubt Dinosaurian; but except in the fact that the neural arch is lost, there is no sign of immaturity. The articular ends are perfectly ossified and almost flat; and though the specimens are a trifle worn from rolling, I have no doubt that they must be referred to a fairly well-developed animal. The larger and better-preserved vertebra has the centrum $1\frac{1}{2}$ centim. long, with the sides somewhat converging, but well rounded below. There is the base of a transverse process, seen in the middle of the side, just below the pit for the neural arch. This circumstance determines the vertebra as an early caudal. The transverse measurement over the bases of these processes is 14 millim. The anterior articular surface is nearly circular, $1\frac{1}{2}$ centim. deep, and nearly as wide, with the margin rounded and the articular surface nearly flat. The posterior articular end appears to have been rather small and rather more concave. The neural arch did not extend the whole length of the centrum. The neural canal is concave from front to back. There are no signs of facets for chevron bones.

The second vertebra is about $1\frac{1}{4}$ centim. long, but had a keel on the base of the centrum. It appears to have been smaller than the other; but, as the dorsal half of the centrum is not preserved, it may be that this is a similar caudal vertebra.

There is no evidence that these vertebræ belong to the animal which possessed the limb-bones; and I have noticed them here because they are not obviously referable to any of the other species described.

Hoplosaurus ischyrus, Seeley.

In June 1880 I received word from Prof. Suess that another collection of Cretaceous reptile remains from the Gosau beds existed, which was discovered long before the publication of Dr. Bünzel's paper. Eventually this small series was secured by Prof. Suess, and forwarded to me. The specimens are imbedded in a hard calcareous clay, and are in a bad state of preservation, having been fractured in the contortion of the rocks to an extent that often makes identification of the fragments extremely difficult. Prof. Suess remarks of the collection, "It is not very much—a few broken articular ends of limbs, a number of those thick roof-shaped dermal plates well known to you, and a few fragments of vertebræ—the whole imbedded in a number of hard fragments of calcareous clay evidently once united together, and clearly belonging to the same individual; so they may be of some interest as showing to which limb-bones the dermal plates belong." They are certainly the most unpromising set of fragments that I ever examined with a view to the study of a new type of life; and yet they certainly indicate a different species from any of which the other collections give evidence. I have removed the matrix, and offer a few notes on some of the more characteristic fragments.

Proximal end of right Humerus.

This fragment indicates a humerus very different from any thing with which I am acquainted, but perhaps makes a near approximation to that reptilian humerus described by Mr. Hulke as probably referable to *Hylæosaurus*. It has lost the radial crest, which appears to have been reflected downward more conspicuously than in Mr. Hulke's specimen, and to have presented more of the Crocodilian conformation, though it extended up to the articular head of the bone, as is usual in Dinosaurs. The superior surface has been fractured, so that the entire thickness of the humeral articulation is not demonstrated; but it was evidently oblong, and measures $6\frac{1}{2}$ centim. in width, and, as preserved, is 4 centim. thick just internal to the radial crest, and over 3 centim. thick above the ulnar tuberosity. It appears to have been comparatively flat, and is remarkably pitted with the evidences of a cartilaginous epiphysis. It appears to be inclined at a considerable angle towards the radial side of the bone. Towards the ulnar side it is rounded. On the ulnar margin it is constricted; and a portion of a tuberosity remains on the inferior surface which is 2 or 3 centim. below the articular head, and increases the transverse width of the bone to about 8 centim., thus giving to the head of the bone a blunt wedge-shaped aspect; a concavity completely separates the tuberosity on the inferior surface from the articular head. Unfortunately I have not found it possible to clear away the matrix from the inferior surface, except so far as was necessary to show that there was a concavity behind the radial crest. The radial side of the bone is flattened, but a little concave from side to side on its external aspect. It forms a considerable angle with the superior face of the bone, from which it is divided by the ridge or tuberosity which formed the ball-like part of the articulation; though this ball is fractured, it was placed conspicuously towards the radial side; and beyond it is a longitudinal concavity. The fragment is only about 7½ centim. long, and the fracture is not sharp; but it shows that the shaft was becoming remarkably flattened and compressed, especially towards the ulnar side.

The specimen thus presents a very marked difference from the humerus of *Anoplosaurus*, and is unlike that of any other genus, especially in the constriction which defines the ulnar tuberosity and in the angle which it makes with the head of the bone.

There is a small fragment which might well be a part of the middle of the shaft of this specimen, too imperfect for description; but if it really pertained to this bone, it may be interesting as showing a thickness of nearly 2½ centim.

A third fragment, very imperfectly preserved, I am disposed to regard as the distal end of the right humerus, though it is so imperfect that I cannot speak confidently on the matter. It only shows one condyle, which is almost globular, with the flattened lateral margin of the bone and a small adjacent part of the superior surface of the shaft. This condyle, however, is remarkably massive, is rounded, less than 4 centim. thick, and 4½ centim. wide, with a rugous articular surface extending internally parallel to the external lateral surface of the bone, and indicating, if I have correctly guessed the nature of the fragment, that the ulna developed a process received between the condyles in an unusual manner. The bone was evidently concave from side to side in front and greatly compressed between the condyles, very much as Mr. Hulke has represented in *Hylæosaurus*; it was thick on the ulnar side, and evidently more compressed on the radial side.

Articular ends of Scapulæ.

The scapulæ are fractured so that the entire blade of the bone is lost as well as the articular surface for the coracoid; so that nothing remains but the articular region. The left scapula is rather more perfect than the right. The specimens have, at first sight, rather the appearance of articular ends of caudal vertebræ than of scapulæ. The left specimen shows the articulation to have been an elongate ovoid with the internal margin of the articulation convex and the external margin more flattened. The extreme width is 4½ centim., and the length about 6½ centim., as preserved. The articular surface was moderately rough, with the margin slightly rounded; and it was concave from front to back. Just above the posterior rounded termination of the articulation the bone is thickened so as to form a very slight tuberosity, most conspicuous on the internal surface, where a groove divides it from the articular head. This inferior surface of the bone is convex from side to side, but soon becomes compressed, so that the blade, where fractured, at 4 centim. from the articulation, is less than 2 centim. thick. On the external surface the specimen is concave above the articulation, partly because there is a slight rounded ridge on the posterior edge, not, however, separable from the rounded posterior border, and partly because the bone is becoming thickened anteriorly, evidently in relation to the development of a strong spine or crest at about 2 or 3 centim. above the articular surface. The articular margin is marked with longitudinal lines of ligamentous attachment. It is of course impossible to speak of the affinities presented by this form of scapula; but the bone appears to me to be distinct from the scapula of *Cratæomus, Anoplosaurus*, *Iguanodon*, *Scelidosaurus*, and other types with which it might be supposed to be allied.

A flat expanded bone, very imperfectly preserved, appears to be a portion of a coracoid. It has but one margin remaining, which is straight for a length of upwards of 5 centim. and indicates an articular surface at right angles to the bone, such as may have adjoined the scapula. The specimen is upwards of 7 centim. broad and 10 centim. wide, as preserved, but is too imperfect for description.

Vertebræ.

The vertebral fragments have shared in the general fracturing. There are two portions of sacrum which had thoroughly decomposed before fossilization. One fragment indicates two vertebræ ankylosed together; the other fragment I regard as showing the base of the centrum of another vertebra, and on this evidence should infer that there were at least three, and probably four, sacral vertebræ, though the second specimen is imperfect in every direction, so that it has to be regarded carefully to be accepted as a vertebra at all. This fragment, as preserved, is 5 centim. long, broad, rounded on the under side and somewhat flattened, with a shallow median depression which is fully 1 centim. wide.

The same characters are shown in one of the ankylosed vertebræ. These also are imperfect at both ends, so that it is impossible to judge what the length of each centrum may have been; but, as preserved, the length of the two together is a little over 5 centim.; and 3 centim. of this belong to what I regard as the more anterior of the two. This vertebra is very slightly concave from front to back, and convex from side to side, with the aspect of being flattened on the under side and with a very slight median depression, which becomes more marked in the second vertebra. The sides are rounded and concavely impressed between the transverse processes. This appears to have been given off at the suture between the two vertebræ, which is somewhat elevated and expands laterally—though, from the fractured state of the specimen, it is impossible to state the width across the vertebra, which, as preserved, is only 5 centim., but may perhaps have been somewhat more. The centrum appears to have been depressed, as usual in the sacral region, but there is no fracture showing its exact thickness. This form of vertebra is very different from that referred to *Iguanodon* by Prof. Owen (Pal. Soc. 1854, pl. 3), in which the base of the centrum is a sharp ridge. It is also unlike, but nearer to, the centrum represented by the same author, pl. 7, and referred to a young *Iguanodon*, in which the base of the centrum is flat, with a sharp ridge margining each side.

There are two vertebræ which appear to be caudal—one from the early part of the tail, the other from the later part of the tail. Both appear to have been equally long; and both are crushed. The earlier caudal vertebra, as preserved, has the centrum about $4\frac{1}{2}$ centim. long, and 22 millim. wide in the middle of the base. The anterior face appears to have been concave, and, as preserved, is $4\frac{1}{2}$ centim. deep; the depth of the posterior end of the bone is somewhat less. The base is flattened, though concave in length, and separated from the sides by a sharp angular ridge. The sides of the bone are concave. The transverse process appears to have been placed on the hinder part of the centrum, below the neural arch, and to have had an antero-posterior extent of no more than 17 millim. The neural arch is compressed from side to side and constricted from back to front, with a rounded ridge margining the straight outer border of the neural arch, which is inclined obliquely backward. The zygapophyses are imperfectly preserved. The posterior zygapophyses extend beyond the centrum; of the anterior zygapophyses no trace is preserved. The later caudal vertebra has a constricted dicebox-like form. Its contour appears to have been five-sided at the articular ends, with a median ridge on the base and lateral ridges at the middle of the sides. The length of the centrum is about 5 centim. Its depth appears to be about 3 centim., and its width $3\frac{1}{2}$ centim. This I take to be at the posterior end of the bone. Only an indication of the neural arch is preserved; the width of the canal increases posteriorly as usual. Another vertebra, apparently dorsal, is imbedded in the matrix; but I have not felt justified in excavating it so as fully to display its characteristics.

Dermal Armour.

The dermal armour comprises plates of two patterns:—first, more or less circular plates of moderate thickness; and angular plates which are thick at one margin, thin at the opposite margin, and have the surface concave in one direction and convex in the other. They are flat on the under side. One or two of the small biscuit-like plates present that curious angular combination of fibres that is characteristic of the armour referred to *Hylæosaurus*, a character which rather suggests the etched surface of a meteorite than the structure of ivory. I have been led to think that this armour of Hylæosaurian character is probably abdominal, or at least was not placed in a position so exposed on the sides of the body as the larger and thicker scutes. One of the plates, as preserved, is 6 centim. long, less than 5 centim. wide, has the margin rounded, and not more than ½ centim. thick (Pl. XXXI. fig. 11). It shows the fibres crossing somewhat obliquely, so as to define slightly rhombic areas. This structure is suggestive of the transverse crossing of the fibres in ivory; but I have no evidence whether it extends into the substance of the bone.

Another plate of about the same size appears to be rather thicker, and, though retaining traces of the cross angular markings, has the surface of the scute a good deal pitted and marked in lines with fine vascular perforations. The larger scutes appear to have lost the cross striping and to show a more porous texture. They are remarkable for having the angle on the scute placed so near towards one margin as sometimes to make that side all but vertical to the base. The other side covers nearly the whole superior surface of the scute, and presents the curious saddle-shaped form to which attention has already been drawn. One of these scutes is 6½ centim. long, and has the angular crest 2½ centim. high, while the average thickness of the plate is not much over 1 centim. In another specimen the crest appears to rise considerably higher, and gives evidence of median compression and oblique overlapping; the base is slightly concave.

Besides these remains there are portions of ribs, which are slender, straight, flattened, or slightly grooved on one side and convex on the other, with the anterior margin of the bone rounded and the posterior margin compressed to a sharp ridge. These fragments are all short enough to appear straight, and have a width of about 1½ centim. There are a few fragments which give some information about the characters of the articular ends of some of the larger limb-bones; but they are so obscure that I have not felt justified in attempting to describe them; and there is a fragment which may be a portion of an ilium, of unusual shape.

Crocodilus proavus, Seeley.

The remains of a procœlous Crocodile, some of which were figured by Bünzel (pl. i.) comprise 2 cervical vertebræ, 8 dorsal, one lumbar, one sacral, an early and a late caudal, portions of two iliac bones (which unfortunately exhibit no characters of value), the proximal end of a femur showing the typical Crocodilian characters in a very pronounced manner, and the ulna and radius. There are Crocodilian teeth which have lateral ridges and striated crowns, and small successional teeth, and a parietal bone.

There is also evidence of a minute Crocodile in the articular head of a femur. The fragment is too small for description; but it obviously indicates a distinct species from the larger remains, as shown by the greater forward curvature of the head, its relatively greater width, and the stronger development of the median crest on the under side of the articular surface.

Femur.

The proximal fragment of the femur (Pl. XXIX. figs. 7, 8), which may have belonged to the same animal as the vertebræ, is $6\frac{1}{2}$ centim. long, exhibits the usual sigmoid flexure, and is compressed on the external or superior surface as in living Crocodiles. Unfortunately the posterior margin of the head is not quite complete; but from the region of the great trochanter a powerful muscular ridge, defined by a groove on its anterior side, runs obliquely downward, outward, and forward, exactly as in the living Alligator; only the muscular power appears here to have been greater. The shaft of the bone is similarly subcylindrical; and the ridges are distributed in exactly the same way. The inferior surface of the bone shows the articular head to have been rather better developed than in the Alligator, apparently a little broader, and curving a little more inward. The median process is more developed, and extends as a distinct ridge for a short distance down the shaft. The muscular tuberosity which represents the lesser trochanter in Mammals and the trochanter of Dinosaurs generally, seen in the middle of the shaft, is better developed than in the recent type. There is an oblique oval depression with an elevated ridge behind it, and another ridge extending above it proximally. The posterior ridge runs proximally towards the articular head, and is separated from the ridge above the muscle by a groove. Every thing which distinguishes the living Crocodile is here intensified.

Proximal end of Right Fibula.

The specimen which Bünzel regarded (pl. vi. figs. 12, 13) as the rib of a lizard presents all the characters of a small crocodilian fibula, in which, as compared with living forms, the crocodilian attributes are somewhat intensified. But the bone-tissue is so dense and brilliant that it has more the aspect of the bone of a bird, Ornithosaur, or Lacertilian. The fragment (Pl. XXVIII. figs. 10, 11) is about $3\frac{1}{2}$ centim. long, and has been obliquely fractured below the expanded head, with a minute displacement which slightly augments the curvature of the bone.

The articular head is relatively thicker than in the Mississippi Alligator, measuring fully 11 millim. from front to back, and 7 millim. from side to side. The articular surface is somewhat saddle-shaped as in the living animal, being concave in length and convex in width. It is widened a little posteriorly, owing to the development of an oblique muscular ridge, which in the existing crocodile does not approach so near to the articulation and is less internal. The internal aspect of the bone is less flattened than in the Alligator, is similarly marked below the articulation with short muscular ridges; but they are not defined by a V-shaped area, and hence the longitudinal tibial ridge, which is well marked proximally, does not originate in a Y-shaped form. The anterior margin of the bone is convex from above downwards; and there is a corresponding concavity in the length of the posterior outline. The external surface was presumably convex from side to side, though (owing, I think, to crushing) it has a longitudinal groove. There is a small muscular tuberosity on the outer anterior margin, as in the Alligator, just where the compressed and curved proximal end merges into the straight and nearly cylindrical shaft. The shaft at the fracture is 7 millim. long by 6 millim. wide, and has a medullary cavity which is over 2 millim. in diameter (fig. 11).

Ulna.

With the radius figured by Bünzel, pl. vii. figs. 7, 8, occurs an ulna. The radius was regarded as that of a lizard. The ulna, which is slender and compressed, with a somewhat expanded proximal end, is exactly paralleled by some of the living short-snouted Crocodiles. The ulna (Pl. XXIX. figs. 9, 10) is $6\frac{1}{2}$ centim. long, and referable to the left side of the body; it has the shaft smooth, compressed from side to side, and contracting and curving as it descends from the humeral to the carpal surface. The articular head of the bone (fig. 10) is remarkably large, being in antero-posterior measurement over 17 millim., while the width is 11 millim. towards the radial border, and about 1 centim. at the posterior border. This surface is somewhat concave from front to back. Immediately below the articulation at the proximal end is a deep impression, which may possibly be due to pressure, but may also indicate the entrance of a large vessel into the bone. On the superior aspect there are natural impressions in the middle of the side and below the inner margin of the articular surface. The thickness of the shaft just below the articular head is 5 centim.; and though this thickness becomes reduced a little in the middle of the shaft, there is a slight thickening again towards the distal end. The width of the shaft just below the articulation is 1 centim.; and this width diminishes to about 6 millim. just above the distal articulation. On the superior surface of the distal end of the shaft a ridge appears at the hinder margin, which extends obliquely across the bone. The distal end is a little crushed and twisted, subreniform, more than 1 centim. wide, and 6 millim. thick, and makes an angle of about 45° in the plane of its direction with the proximal end. The form of the articulation appears to include three regions—first a deep middle groove, external to which is a small spherical ball, while internal to it is a concavity. The median groove and the compression of the bone on the inferior margin give to the articulation somewhat of a broad V-shape.

Radius.

The radius is represented by both right and left bones. The specimen figured by Bünzel (pl. vii. figs. 7, 8) appears to me to be left. It is a straight bone, 6·2 centim. long, corresponding in length with the ulna. The proximal end (Pl. XXIX. fig. 13) of the bone is expanded transversely, with a thickened margin on the inferior border. This end of the bone is fully 1 centim. wide, but, as preserved, is only $\frac{1}{2}$ centim. thick, probably owing to crushing of the superior articular border.

The shaft (fig. 11) rapidly contracts, so that at a little below the articulation it is hardly more than ½ centim. wide; but it gradually expands distally to 1 centim. The bone is compressed from above downward; its thickness in the upper half of the shaft is 4 millim.; but it increases in the lower half of the shaft to over 5 millim., owing to the development of a median ridge which divides this part of the bone nearly equally into internal and external areas, which are margined laterally by ridges. The inferior surface is also marked towards the distal end by a slight longitudinal median ridge; and the articular end of the bone is subreniform, convex from side to side. The width of the distal end (fig. 12) is 1 centim.; and its thickness in the middle is about ½ centim. The distal ridges are an important distinctive character not found in living Crocodiles.

Cervical Vertebræ.

The cervical vertebræ are probably about the third and fourth. What I take to be the third is only the centrum, and, except in less development of the tubercle for the ribs, differs in no essential point from the better-preserved bone. The fourth vertebra (Pl. XXX. figs. 6, 7) might, indeed, be the fifth, sixth, or seventh, since it presents all the characters seen in the vertebræ of the Alligator in the middle of the neck. It is about the size of the vertebra figured by myself as that of *Crocodilus cantabrigiensis*, but is shown to belong to a distinct species by the less antero-posterior length of the neural arch, its greater inclination forward, the stronger development of the hypapophysial spine, and minor characters.

The centrum is 17 millim. long, terminates posteriorly in a well-rounded articular ball which is about 4 millim. long, and is margined below by a sharp ridge and above by an equally sharp incised groove (which may perhaps indicate a certain incompleteness of ossification). The ball is circular and as nearly as may be a centimetre in diameter. The cup in front is of corresponding size and form. The hypapophysis is a strong compressed process which rises just in front of the ridge bounding the posterior articulation, and is directed forward and downward in front of the anterior cup, much as in the fifth cervical of the Mississippi Alligator. On each side of this process and below the middle of the side of the centrum, but rather higher than the corresponding process in the Alligator, is situate the parapophysis or articulation for the rib. It blends with the margin of the anterior cup, and is a strong, compressed, triangular process with a flattened facet which looks obliquely outward and forward. It is separated from the hypapophysis by the usual concave channel (fig. 6); and a similar channel divides it from the diapophysial process on the neural arch; but in the middle of this channel, or, rather, towards its upper part, is a slight ridge which extends from the upper margin of the anterior cup backward towards the ball. The diapophysis, as usual, extends further outward than the parapophysis, and is a smaller facet supported on a process of which the hinder margin is no more free than in the third vertebra of the Alligator; but the process is broad, and defined below and in front by an oblique groove. The vertical measurement across the two facets for the cervical rib is 1 centim. The neural arch has a decided aspect of being inclined forward, owing to the way in which the slight rounded ridge from the diapophysis ascends obliquely forward towards the præzygapophysis, coupled with the fact that the posterior border of the neural canal is straight and parallel to it. The antero-posterior measurement of the neural arch below the zygapophyses is less than a centimetre. The sides of the neural arch are concave from above downward, and obliquely channelled. The præzygapophyses are strong processes compressed into a wedge-shape in the usual way (fig. 7), directed upward, forward, and outward, with circular facets, which are divided from each other by a broad V-shaped notch. The processes are united by a thin platform above the neural canal, the anterior half of which is excavated by a longitudinal pit which almost, or quite, perforates the forked depression between the zygapophyses. From the hinder half of the neural platform, which has a remarkably four-cornered appearance owing to the lateral constrictions, rises the neural spine. It is triangular, being compressed in front and wider behind, where it is vertically channelled; and the channel descends so as to divide the posterior zygapophyses from each other. The antero-posterior measurement of the base of the spine is $\frac{1}{2}$ centim. Its height, as preserved, from the base of the zygapophysial facet is $1\frac{1}{2}$ centim. A slight ridge extends from its anterior border to the posterior border of the præzygapophysial facet, while in the Alligator the corresponding ridge, when it exists, is carried forward; behind this ridge the platform at the base of the neural arch rounds convexly on the side of the centrum. The posterior zygapophyses (fig. 6) are strong wedge-like processes directed outward, only slightly extending behind the neural spine, and not entirely behind it as in the Alligator. They are remarkable for the well-defined notch below them, something like that seen in the third and fourth vertebræ of the Alligator, and for the tubercle above the posterior margin of the ovate facets, which gives the back of the zygapophyses a somewhat channelled appearance, to which the Alligator offers no parallel. The measurement from back to front over the zygapophyses is 2 centim. The transverse measurement over the præzygapophyses is about 18 millim. The side-to-side measurement of the constriction between the anterior and posterior zygapophyses is 12 millim. The posterior zygapophyses were evidently narrower than those in front by a millimetre or two. The neural canal is transversely ovate behind, but in front appears wider and more depressed (fig. 7), with a flat wall; the floor of the centrum is concave, and shows the usual pair of nutritive foramina.

Dorsal Vertebræ.

There are 8 dorsal vertebræ, which mostly belong to the hinder part of the series. Reckoning as the first dorsal that vertebra in which the rib is for the first time entirely carried on the transverse process, I should regard the earliest vertebra preserved of this series as probably not later than the 6th dorsal, while it might have been as early as the second, which is likely to have been its true position. Then succeeds a centrum which may have belonged to about the fifth dorsal. The remaining six vertebræ appear to be in sequence, and belong to the hinder part of the vertebral column; and if the number of vertebræ was the same in this animal as in the Alligator, they might be the 7th to 12th dorsal vertebræ. The 13th, or last dorsal or lumbar vertebra, if found separately, might have been referred to another genus, and perhaps to a Dinosaur. The first sacral vertebra is imperfectly preserved.

The early dorsal vertebra is distinguished, as in existing Crocodiles, by the slight development of the ridge, which ascends from the hinder border of the præzygapophysis inward and backward towards the neural spine. The centrum has a length of from 18 to 19 millim.; so that there is but little increase of length as compared with the cervical region. The transverse process is compressed and directed outward horizontally or a trifle upward. It is thickened on the inferior posterior border by a ridge which extends downward towards the centrum and constitutes a marked specific character, especially as there is a deep conical pit behind it immediately below the notch which separates the transverse process from the postzygapophysis. The antero-posterior width of the transverse process is 11 millim. Resting upon it in front, rather more horizontally than in existing Crocodiles, so far as regards its lateral direction, is the præzygapophysial facet (fig. 8), which is about 11 millim. long and 6 millim. wide. The transverse process is perhaps a little lower in position than the transverse process in the early dorsal vertebræ of the Alligator, being on a level with the upper part of the neural canal. The ridges on the posterior zygapophyses are rather narrow, so as to give a somewhat pinched aspect to the concave area on each side at the base of the neural spine (fig. 8). The neural spine extended backward a little between the diverging ridges of the posterior zygapophyses; and at its base there is a pit. The centrum is evenly rounded (fig. 9), and both cup and ball well developed. As in the cervical region, the ball is marked on its upper margin by an incised groove (fig. 8) similar to that seen in the vertebræ of the Alligator.

The later dorsal vertebræ, as in existing Crocodiles, are characterized by the deeper depression between the anterior and posterior zygapophyses, and by the increased elevation of the zygapophyses above the transverse process, consequent upon this process acquiring a somewhat lower position relatively to the neural canal. The præzygapophyses come to extend a little further forward and to look a little more upward and inward. The centrums increase in length so that what I regard as the tenth is 23 millim. long. The articular cup in front, perhaps, becomes a little wider; and the base of the centrum is rather more flattened. The compressed appearance at the base of the transverse process gives place to a regular concavity from above downward; and the antero-posterior extent of the neural arch is increased, while the size of the neural canal is diminished and its height lessened. There also comes to be a less development of the inferior margin of the cup of the centrum, which gives a slight appearance of leaning forward to the bodies of the vertebræ. The twelfth centrum is 22 millim. long, and has the cup 13 millim. wide in front, showing an increase in the depression of the centrum similar to that which is observed in the later dorsal vertebræ of existing Crocodiles.

Lumbar Vertebra.

The lumbar vertebra (Pl. XXX. figs. 10, 11) may not have been the only one of its kind; it certainly did not immediately succeed the last dorsal, if it is supposed to have pertained to the same animal; for it has the centrum much more depressed, with the zygapophysial facets perceptibly higher, but still retaining a much less inclined position than is seen in the Alligator. The cup in front of the centrum (fig. 10) is 1½ centim. wide, and, as preserved, 1 centim. in vertical diameter; so that it has a transversely oval form, which gives a broad aspect to the base of the centrum. The posterior ball has a similar pterodactyle-like transverse extension, but, as in the earlier vertebræ of the series, is margined above by the characteristic groove. The transverse process is only 7 millim. wide at the base, and was therefore small, like the corresponding process in the Alligator. In transverse section (fig. 11) it is somewhat T-shaped, owing to the development of an inferior sharp vertical ridge which descends to the base of the neural arch, widening as it comes downward. This ridge curiously resembles that which is so characteristic in the neural arch of a Dinosaur; but it is clearly comparable to that which I have referred to in the early dorsal vertebra, and constitutes one of the distinctive characters of the species. The neural canal here enlarges again as though in anticipation of the sacral expansion. The notch between the posterior zygapophyses is wider in this vertebra than in the dorsal series; and the zygapophyses appear to be somewhat stronger and broader.

Sacral Vertebra.

The first sacral vertebra is only a fragment, the greater part of the neural arch being broken away, only a portion of it remaining at the anterior end of the left side. The centrum is remarkably oblique; it is 2 centim. long, and flattened on the under side, with a small median groove in the anterior part. The sides are rounded; the anterior cup is imperfectly preserved, but appears to have been more depressed than in the lumbar vertebra. The posterior end of the centrum is oblique, flattened, with a depression below the neural surface. It is narrower than the anterior end, being about 11 millim. wide, as preserved, and semicircular in outline. The basal surface of the neural canal is smooth, straight, and concave from side to side. The neural arch enters into the anterior cup as in the Alligator, and gives off at the anterior end of the side a massive transverse process, the fractured base of which is 13 millim. deep and 1 centim. wide, and has a somewhat reniform outline owing to the anterior concavity. Only the base of the anterior zygapophysis is preserved.

Caudal Vertebræ.

The early caudal vertebra was probably about the fifth or sixth. The late caudal vertebra would correspond with about the 23rd or 24th in the Alligator, though the form of the centrum might be taken to indicate that the tail was relatively short, and probably contained fewer vertebræ, while, from the absence of any continued series, its identification as belonging to this species is open to some doubt. The early caudal vertebra (Pl. XXX. figs. 12–14) is of elongated form, compressed at the sides, narrow and somewhat flattened on the underside. The length of the centrum is 31 millim. The cup in front (fig. 14) is circular and 11 millim. in diameter; below it is an oblique hypapophysial facet. The cup is slightly oblique; and the length of the base of the centrum is 22 millim. Posteriorly the outline is subquadrate, owing to the flatness of the sides and to the development of two facets divided by a groove below the articular ball (fig. 13). Unlike the Alligator, the centrum is widest over these facets. There is the incised margin on the upper surface of the ball which characterizes all the vertebræ. The width of the posterior end of the centrum is 1 centim., its extreme depth 13 millim. The centrum has a pinched-in appearance (fig. 13) below the transverse process (fig. 12), which, as usual, was given off about the middle of the side, was horizontal, compressed from above downward, and, though convex on the underside, shows no indication of a ridge. The antero-posterior extent of its base is about 12 millim. The neural arch appears to have had a very short neural spine; and the ridges from the zygapophyses, instead of being directed downward to join the transverse process as in the Alligator, converge inward and backward to form the base of the neural spine in front. The anterior zygapophyses projected in front of the centrum; the facets (fig. 12) looked more upward and less inward than in the Alligator; and there was no notch between them exposing part of the neural surface of the centrum.

The late caudal vertebra, supposing it to belong to this species, concerning which I feel some doubt, is about 17 millim. long, has a ridge in place of the transverse process, has the narrow base margined by two sharp parallel ridges, and the posterior cup deeper than the anterior cup.

Teeth.

There are 5 Crocodilian teeth. The most important of these (Pl. XXVII. fig. 25) is fractured, but appears to indicate an ovate crown curved slightly inward, terminating on each side in a strong ridge, and having the exterior face marked with a number of faintly elevated blunt striæ, with finer striæ on the inner face; the crown, which is a little worn, is 1 centim. high, and gives indication of the beginning of the fang. There are two successional teeth; one of these has a circular base, the other an oval base; both are short and blunt, marked with lateral ridges and covered with numerous fine parallel striæ. The largest is nearly ½ centim. in diameter (fig. 24).

Another tooth has the same general character; but the crown appears more curved, with sharper lateral ridges and finer and more numerous striations.

In the possession of lateral ridges, as well as in the striated surface of the crown, the teeth of this species approximate to those referred by Leidy to *Hyposaurus*; but there is no correspondence in vertebral characters. The vertebræ referred by the same author to *Thoracosaurus* correspond in being procœlous, but differ in the position and character of the tubercles for the articulation of the ribs, as well as in the form and direction of the neural spine in the cervical region. It is difficult to determine accurately the relation of the species to *Holops*; but the absence of the hypapophysis from the early dorsal vertebræ will exclude comparison with that form, equally with the contour of the neural canal. *Holops*, however, appears to have had the sharp ridge margining the parietal bone which is seen in the specimen figured by Bünzel.

It is impossible to determine whether the parietal bone of Crocodilian character (figured by Bünzel, pl. i. figs. 1–2), is referable to this species or to some other animal. Its distinctive features are the sharp lateral ridges margining the temporal fossæ, the fineness of the circular pits on the bone, and the remarkable thinness of the bony substance.

That this species can remain in the genus *Crocodilus* is improbable; but at present I see no grounds on which to separate it.

Pleuropeltus Suessii, Seeley.

Postfrontal Bones of a Chelonian Skull.

Two fragmentary bones (Pl. XXVIII. figs. 8, 9), right and left, present on their external surface impressions of scutes, and on their under surface portions of a large cavity which I believe to be orbital; therefore I interpret these fragments as being postfrontal bones of a large Chelonian of Emydian affinities; and as the skull, when complete, was obviously of large size, it may well have belonged to the animal indicated by the large costal plates presently to be described. The remarkable feature about this bone is the character of its sutures; for while a groove runs round the thin margin in which the edge of the bone terminates, and evidently received a sharp ridge from the adjacent bone, the margin on the under side is bevelled, and thus demonstrates a union of the bones by squamous overlap. The under surface of the bone (fig. 9) is crossed by an oblique ridge, which divides it, as preserved, into two nearly equal portions. This ridge helps to form a part of the posterior boundary for the eye-ball, and is characteristic of *Chelydra* and allied genera. The orbital surface is concave, and more resembles that of *Chelydra serpentina* than that of *Trachydoglossus*; and the resemblance extends even to the position of the vascular foramen at the back of the orbit, though there may, perhaps, in the fossil be several small foramina in a line. This surface, as preserved, measures about 4 centim. in its greatest length, and upwards of 3 centim. in its greatest width. The bone probably extended forward no further than the middle of the orbit; and in that case but a small portion is lost. The area posterior to this ridge bounding the back of the orbit is excavated, 4 centim. long and 2 centim. wide. It consists of an inner oblong area, truncated externally by the suture for the malar bone, and margined by the bevelled edge referred to, which is about 6 millim. wide behind and 8 millim. on the inner side. The superior surface of this subquadrate fragment (fig. 8) is convex from within outward, showing that the top of the head was flattened, but that it rounded into the lateral area. It is divided into seven areas by unusually wide and well-marked scutal grooves. The bone between these grooves has a roughened, somewhat pitted appearance, indicative of vascular structure. The scutes are especially remarkable from their number and small size; that over the orbit is largest, being about 3 centim. long and more than $1\frac{1}{2}$ centim. wide. The other scutes will be best understood from the figure. They are irregular, subquadrate or subtriangular figures, varying in measurement from 1 centim. to about $1\frac{1}{2}$ centim. The grooves which define the scutes are from 2 to 3 millim. wide. The articular surface for the malar bone (fig. 9) is $2\frac{1}{4}$ centim. long, and over a centimetre deep. It is a concave shallow groove, which involves the termination of the postorbital ridge. There is every reason to suppose that the squamosal articulation was a small area just behind the malar articulation, and that it did not extend for more than a centimetre. Hence the inner and posterior bevelled articular surface, which becomes very thin behind, is related to union with the parietal bone. The posterior portion is oblique, and makes an angle of 45° with the interior portion, which is straight and parallel to the orbital margin. Three scutes are crossed by the parietal suture, which, indeed, is the case in the skull of the Common Turtle. In front of the parietal suture, commencing with the most anterior inner scute, is a distinct suture, which prolongs the line of the parietal, and therefore gave attachment to the frontal. The portion of the right postfrontal bone includes four scutes and a fragment of the inner part of the postorbital ridge, extending as far forward as the termination of the parietal suture.

Costal Plates.

Dr. Bünzel figured a remarkable specimen, which he regarded as the left ilium of an animal named *Danubiosaurus anceps*, the supposed rib of which proved to be a Dinosaurian scapula. I find a second specimen of this supposed ilium, less perfect, but similar in character, evidently coming from the opposite side of the body. For reasons to be mentioned, I have no hesitation in interpreting these specimens as ribs to which dermal plates are ankylosed. But there is something very different here from what is observed in ordinary Chelonians; and though I have no doubt that we have to do with a pair of Chelonian costal plates, the type indicated by these remains is new. It would, indeed, have been less startling to refer the specimens to any part of the skeleton of a Dinosaur or lizard than to the Chelonia; for these fossils, if rightly interpreted, indicate an animal with a relatively larger vertebral column than any Chelonians now known, or at least with a vertebral column constructed upon a different plan. The ribs were wide, as in the marine Chelonia, and extended distally far beyond the limits of the plates which covered them. The superimposed plate is developed chiefly behind the rib; its anterior margin is smooth and rounded; the posterior margin is not preserved, but obviously became thin. The free articular end of the rib was massive; and the superimposed plate extended beyond it proximally for an unusual distance, indicating great width for the intervening vertebra. This portion of the dermal plate, which extends mesially beyond the rib, has the external surface well preserved, but wants the smooth ossified internal surface; and as this is absent in both specimens, it is possible that in the living animal this internal part of the plate may have been cartilaginous or united to other bones. Neither of the specimens gives the slightest indication either of external scutes or ornament, or of union to adjacent bones; and the external surface is such as would suggest that the bones were probably contained, if not beneath a muscular covering, at least beneath a skin which had not become specialized; so that we have here an animal that in some respects recalls the *Protostega* of Prof. Cope, but differs essentially in the dermal plates being blended with the ribs. An allied but undescribed type from the Cambridge Greensand also has the costal plates separate from each other, but differs in having them marked with scutes.

A short description of each of these specimens appears necessary. First, the less perfect of the two (Pl. XXX. fig. 15) shows a smooth external surface gently convex in length and somewhat convex from side to side. It consists of a thick dense dermal plate superimposed upon a rib, this plate probably being a representative of the supracostal cartilages and ossifications found in birds, crocodiles, and *Hatteria*. Immediately above the articular expansion of the rib, at the proximal end, the plate is a centimetre thick, and is defined by the density of its texture from the osseous matter of the rib beneath. This bone on the interior surface is much eroded, but presumably extended much further towards the median line of the animal's body, since the dermal plate is prolonged with a rough under surface, due to this bone having adhered to the bone with which it is blended; and as the plate is prolonged mesially, its thickness becomes reduced to one half, though the fractured specimen is imperfect at its margin. The transverse width of the plate, as preserved above the expanded head of the rib, is about 9½ centim. About 9 centim. further away from the middle line of the animal, a length of about 4 or 5 centim. of the margin of the plate is rounded; and here its union with the thin underlapping, transversely expanded margin of the rib is distinctly seen. On the opposite or posterior margin there are some faint indications of a lateral rounding of the margin of the dermal plate. At 18 centim. from the proximal end of the rib the dermal plate comes to an end, being broken away, and allows the rib to project freely from under it, showing, I think, that although there was bony union between these two parts of the skeleton, it was a union established somewhat late in the animal's life. At this point the bony plate is somewhat thinner than at its proximal fracture; the plate tapers apparently outwards, and is somewhat broken away from the anterior proximal margin of the rib. The plate is hence, as preserved, of a lanceolate form; but its outline cannot be accurately stated.

The rib in this specimen differs from the ribs attached to the costal plates of living Chelonians in being coextensive with the plate —that is, as wide as the plate, and, as shown by the other specimen, as long; hence its limits are not defined distinctly in any part of its extent, least so in the proximal part of the bone, where the surface is convex from side to side. This convexity becomes narrower and relatively more elevated as the bone proceeds outward, and is confined to its anterior border; where the rib terminates it is over 3 centim. wide, over 1 centim. thick, and, though compressed on the anterior border, is more compressed on the posterior border. The thickness of the combined rib and plate is about $2\frac{1}{4}$ centim.; but even as preserved, the thickness at the fractured articular end is 7 centim. The underpart of the bone, which is slightly displaced by a fracture consequent upon a minute dislocation, is convexly rounded from side to side, and concave from within outwards, so as to present a saddle-shape. The transverse width of the fragment preserved is about $6\frac{1}{2}$ centim. The anterior border is notched, as though for the passage of an intervertebral nerve, or from the head of the rib being free, as in ordinary Chelonia, though the conformation would rather suggest the former interpretation. There is one curious character in evidence that the expanded lateral part of the rib extended further towards the middle line than the articular head, showing that the ribs had attained an unusual transverse development consequent upon the expansion of the superimposed plates. The transverse width of the head of the rib is 4 centim.; and here the fracture gives it an almost semicircular outline.

The second specimen, already figured by Bünzel, pl. vi. figs. 4, 5, has a length, as preserved, of 48 centim.; of this 39 centim. is occupied by the blended rib and its superimposed dermal plate, the remaining 9 centim. consists of the extension of the plate alone beyond the head of the rib towards the middle line of the body. The plate, where it is presumed to have extended over the vertebra, is thin, and becomes thinner the further it extends, both mesially and laterally. Its margins are imperfectly preserved, but have a wedge-shape. The costal region wants a small portion in the middle of the plate in front; but throughout it has the anterior margin preserved rounded from below upwards, and roughened in the proximal half, as though with ligamentous attachment to the adjacent plate. On the upper surface these lines at first run in a transverse direction, and then run forwards and inwards, just as on the under side they run downward and outward. This oblique direction is strongly suggestive of the oblique crossing of ordinary intercostal muscles. In length the anterior margin of the bone is gently concave. The posterior margin is, unfortunately, not preserved; and the plate is remarkably convex from before backwards above, though this convexity is more marked on what I take to be the posterior side than on the anterior side. The extreme width of the plate below the articular head of the rib is about $13\frac{1}{2}$ centim.; and it gradually tapers as it extends outwards. Distally the thickness of plate and rib diminish; and at the extreme distal end, where the transverse measurement, as preserved, is under 3 centim., the thickness of the combined plate and rib is less than a centimetre. The posterior half of the plate, while smoother externally than the anterior half, is marked with several short, parallel, straight, vascular grooves, which are very narrow; each is about 2 centim. long. This condition leads me to suspect that the anterior part of the rib may have been imbedded in muscle, while, owing to its curvature, the middle of the plate may have had only a dermal covering.

The interior or under side of the specimen has the expanded head of the rib broken away; and while it was placed in the middle of the width of the plate as in the other specimen, the rib soon becomes developed on the anterior border, being limited by a concavity which runs down the length of the bone, dying away with the elevation of the rib at the distal end. This principal part of the rib becomes narrower as it extends further outward; but the fractured condition of the posterior margin appears to indicate that the margin of the rib was prolonged as a thin film towards the adjacent plate.

No similar remains which are referable to an animal of this kind have been discovered.

Scapula of large Chelonian.

The fragment which I identify as a portion of a right Chelonian scapula, indicates an animal of somewhat large size. It shows no trace either of the præcoracoid or the articular end of the bone, which had decomposed prior to fossilization, or of the distal end; so that it is not a fragment giving valuable information concerning the affinities of the animal. The fragment is 9 centim. long, 4 centim. wide at the proximal end, as preserved, and 2 centim. wide at the distal end. The surface which I take to be posterior is smooth, convex from side to side, but more flattened at the distal end than at the wider proximal end. In length the surface is almost straight. The internal margin is concave and sharp, and looks as though it might have been produced into a præcoracoid. The external margin is slightly convex, except towards the proximal end, where it is modified, owing to the bone bending outwards and downwards, as though for the formation of the articular surface. The anterior aspect of the bone is much rougher; and there is a ridge which becomes stronger towards the proximal end, thickening the bone on its outer part, and making it concave in length, and dividing the anterior aspect into a broad, flattened, inner area and a narrower external area. The thickness of the bone towards the proximal end, where fractured, is 2 centim., and the thickness towards the distal fracture 13 millim. This is not an identification in which I feel absolute confidence, on account of the smoothness of one side of the bone and the roughness of the other, which I had not noticed in any Chelonian scapula.

Emys Neumayri, Seeley.

There occur many remains of several Chelonians of moderate size. I only brought to this country a selection of some of the more characteristic fragments, which all belong to the carapace and plastron. It does not seem to me desirable to determine the genera from these specimens; but from their general character rather than from any distinctive characteristics, I regard them as being Emydian. The specimens are as imperfect as any of the other reptile remains, and, as they do not differ much in size or character, are difficult to deal with. There are, however, certain differences of texture and form which justify me in indicating the existence of several species. These are all referred provisionally to the genus *Emys*, pending better evidence of their generic characters. The species are best distinguished by the characters of the plastron; for the hyo- and hypoplastral bones preserved may indicate, even in their fragmentary condition, four species. The bulk of the remains I refer to the largest species, which was fully 25 centim. across the carapace. This species is marked by the depth of the grooves which define the areas of the scutes, and frequently by their elevated borders. Another marked feature is the exceedingly fine subgranular condition of the bone on its external surface—a character difficult to define, but altogether peculiar. Of this species the plastron is represented by portions of the hyoplastral and hypoplastral bones, though from their fragmentary condition, it is not always easy to distinguish between these. One fragment (Pl. XXX. fig. 16) is only $7\frac{1}{2}$ centim. broad and $5\frac{1}{2}$ centim. long; it does not show a single sutural surface, but exhibits the axillary region crossed in its lower part by an oblique scutal impression which runs forwards and a little inwards till it reaches the inner margin of the præaxillary scute, which is prolonged forwards on the superior edge as a strongly marked groove. The usual transverse scutal impression on the basal part of the hyoplastral plate runs a little in advance of the axilla, and, as it nears the lateral margin, is directed angularly forwards in the last centimetre of its length. This scutal impression is strongly elevated; the ascending axillary process was compressed and directed obliquely upwards, forwards, and apparently a little outwards. The thickness of the plate varies from $\frac{1}{2}$ centim. in the inner part to 1 centim in front of the axillary notch.

A second specimen, showing the anterior part of a similar right hyoplastral plate, may, perhaps, belong to the same species though to another individual: the thickness of the scute is the same; the elevated ridge at the scutal suture is the same; though fractured in front, it measures upwards of $4\frac{1}{2}$ centim. anterior to the transverse suture. The lateral margin of the plate is sharp, being bevelled above, with the bevelled area also defined internally by a sharp ridge, interior to which runs a slightly impressed broad prolongation of the supraaxillary impression. In the carapace no neural plate is preserved. The first costal plate (Pl. XXXI. fig. 13) on the left side is nearly perfect; it is slightly arched, rather less than 10 centim. long, and more than 3½ centim. wide at the lateral impression of the first vertebral scute. It shows the oblique sutural surface for the nuchal plate, which has a concave border about 3½ centim. long; the width of the union with the first neural plate is 2½ centim., but was probably more, as the posterior border of the scute is imperfect. The rib is not visibly distinct from the plate upon which it is supported, as it is in some species of *Testudo*; it has a well-elevated compressed head, 7 millim. deep and 4 millim. wide; it is placed obliquely, so as to look forward and outward. In the middle of the plate the rib has become so depressed as to be only just recognizable; it is there 1 centim. wide; but at the outer part of the plate its extremity is prolonged beyond the plate, to unite apparently with the marginal plate. Anterior to it, on the under side, the plate is excavated (Pl. XXVII. fig. 27), and the side of the rib roughly striated, owing to attachment of the supraaxillary process from the hyoplastron. This excavation extends inwards from the extremity of the rib for 4½ centim. A fragment of the right plate shows its depth where it joins the first neural plate to be 3¼ centim., and the greatest depth of the bone to be about 4 centim. There are several fragments of costal plates; but they can only be identified by the scutal markings. What appears to be a third costal plate of the left side is impressed with the transverse border dividing the second and third vertebral scutes for a length of 3¾ centim.; and since at this point the antero-posterior measurement of the plate is only 3 centim., it shows that the vertebral scutes were extremely broad relatively to their length, since the length could not have exceeded 6 centim., while the breadth could hardly have been less than 10 centim. The plate is arched, showing that the carapace was as much elevated as in a testudinate Chelonian. Its extreme length, without reckoning the curve, is upwards of 11 centim.; following the curve, the length is nearly 13 centim. The breadth of the plate, towards the outer margin, is about 3½ centim. Its thickness at the proximal part is 4 millim., and at the distal end 3 millim. On the under side the head of the rib is moderately elevated; but its course down the plate is only just perceptible, and marked by a smoother condition. It does not appear to have been prolonged at the distal margin. A plate from the hinder part of the carapace, which is imperfect, also shows the arched character strikingly. It is remarkable for its antero-posterior extent of nearly 3½ centim., and appears to be the last costal plate. If so, it is impressed on its outer part with a vertebral scute. Hence I infer this animal to have had a nearly circular outline, and to have had the shield greatly elevated. It may be distinguished as *Emys Neumayri*.

Other Species of Emys.

Another species, represented by the remains of more than one example, is, however, known chiefly from the hypoplastral plates. It appears to have been a smaller species than the last, though it is not easy to estimate its size from the distance between the axillæ, or from the breadth of the abdominal scutes. The hypoplastron shows some indication of the median and anterior sutural margins, which would indicate a broad species, after the pattern of the foregoing. The length of the fragment is 6½ centim., and its breadth about 6 centim. The transverse scutal impression is from 2½ to 3 centim. behind the anterior suture. The bone is compressed to a sharp margin, which is prolonged as an elevated ridge for about 1 centim. beyond the inguinal notch. The margin is nearly straight. I regard this ridge as indicative of a well-marked species.

A third species is distinguished by the way in which the axillary and inguinal processes are obliquely overlapped. A fourth species, of small size, is represented by many parts of the carapace and plastron.

Aræosaurus gracilis, Seeley.

Vertebra.

The vertebra of a lizard, figured by Bünzel, pl. vi. fig. 11, is very imperfect, and so badly drawn as to give no just idea of its characters. It is remarkable for the perfectly globular form of the posterior articular ball, which is nearly 6 millim. in transverse measurement, and nearly 5 in vertical measurement. It is margined by an impressed groove, which extends further forward on the neural margin than on the visceral margin. The length of the centrum in the middle line is 13 millim. What remains of the anterior cup is deeply excavated to correspond with the articular ball, with a sharp margin conspicuous on the inferior border. The inferior interarticular surface of the centrum is 1 centim. long; on its base run two parallel blunt ridges, divided by a median groove; external to these ridges are two oblique impressed concave lateral areas, which are broad in front and narrow behind, margined superiorly by an oblique rounded ridge, which ascends from the upper margin of the articular ball towards the middle of the articulation for the rib on the anterior part of the vertebra. This articulation for the rib is a strong process, extending laterally further than the width of the articular cup of the centrum, is concave from above downwards in front, looking obliquely downward and outward, long and narrow, rounded from fore to back, and most elevated proximally. It carries superiorly the præzygapophysis, which was a large oval surface, looking upwards and a little inwards, placed just above the articulation for the rib, and considerably above the intervertebral articulation. The zygapophysis is only preserved on the left side, the portion which had existed on the right side having disappeared before the bone came into my possession. It is impossible from this slender evidence to determine the affinities of this animal.

Ornithocheirus Bünzeli, Seeley.

The remains of Ornithosaurians are unsatisfactory, being, for the most part, either small portions of shafts of bones, or else bones which have been greatly crushed. The fragments of phalangeal bones throw no light on the structure of the animals to which they belong, and give no clue to specific characters. The bone-tissue, however, is somewhat thicker than in English specimens; and I have no doubt the fragments belong to a peculiar species. There is an interesting crushed proximal end of a humerus, showing the form of the head, the immense radial crest, and the ulnar expansion of the bone at the humeral articulation: and this, with some other fragments, characterized by thin texture of the bone, may, perhaps, indicate a second species. But although of great local interest as demonstrating the presence of these animals in a period of time in which they were so plentiful in England, these fragments are of no importance to the anatomist. The only specimen of importance is the articular end of the lower jaw, already described by Bünzel (pl. vi. figs. 6, 7). This bone is obliquely fractured just in front of the articular end, and shows the articular surface and the characteristic keel beyond it. The length of the fragment is 34 millim. The bone is compressed from side to side; and the sides converge downward into a narrow rounded ridge. The external surface is flattened like the internal surface, which latter shows a suture with very irregular margin, nearly parallel to the base, and near to it, indicating that the articular bone was received into the angular bone. The area in front of the articulation contracts from side to side, and is rounded; but on the inner margin there is a large pit partly fractured through, indicating a pneumatic foramen. The articular surface is transversely ovate in area, with a median ridge running obliquely backwards and outwards from the hind margin of this foramen. This divides the articular surface into a triangular concave area in front and towards the outer side, and a posterior groove which is best developed towards the inner side of the jaw. This articulation perceptibly widens the bone at each side. Its width is 13 millim., its length 8 millim. Behind the articulation there is no defining border, like the sharp elevated ridge in front, but the surface is flattened, with the sides slightly converging till they terminate in the rounded extremity. This posterior area is directed obliquely downwards to the base of the bone. The inner half of its surface consists of a pneumatic foramen, which is 13 millim. long, and reaches forwards to the posterior articular groove. This jaw seems to be well distinguished from the species already described.

Conclusion.

From this survey it appears that Dinosaurs were well represented in the Gosau beds. Most of the remains belong to two species of a quadrupedal carnivorous genus *Cratæomus*, which in many respects resembles *Scelidosaurus*. It is just possible that *Struthiosaurus* may prove to be the same genus, or may have possessed the teeth referred to *Cratæomus*. The genera *Hoplosaurus*, *Oligosaurus*, *Rhadinosaurus*, and *Ornithomerus* are only known from a few bones each; *Megalosaurus* merely from teeth. It is just within the limits of possibility that *Doratodon* may prove to be the jaw of *Rhadinosaurus*; but it is not likely to belong to the Crocodile, because true Crocodilian teeth occur. Hence there are certainly, with the *Mochlodon*, seven Dinosaurian genera, while there may be as many as ten genera. Of Crocodiles, Lizards, and Pterodactyles there are certainly at least one each. The Chelonians are represented by two genera and five species, two only of which are described. Thus the Gosau fauna includes in all fourteen genera and eighteen species of reptiles; and there is every reason to suppose that these formed but a part of the Reptilia living when the deposits were formed.

I can scarcely hope that my efforts have been in every case successful in determining the species to which these disjointed and often fragmentary bones should be referred; but I have throughout worked on the basis of anatomical structure, and indicated only such species and genera as the organization of the animals made inevitable.

I have now only to express my gratitude to Professor Suess for his kindness in allowing me to study this collection and retain the specimens so long in this country; and I would also express my thanks to Prof. Ramsay for permission to figure the skull of *Acanthopholis*; and to the Council of the Royal Society for assistance in carrying on this research.

APPENDIX.

Note *on the* Gosau Beds *of the* Neue Welt, West *of* Wiener Neustadt. By Prof. Edward Suess, F.M.G.S.

The Gosau beds have been deposited in *preexisting* valleys of the Triassic and Rhætic portion of our North-eastern Alps, and have suffered so much subsequent folding and dislocation that in the valley of the "Neue Welt," the spot where the bones were gathered which I sent to you, several shafts pass twice through one and the same seam of coal. The Gosau beds usually form green slopes at the foot of the great mural precipices of Triassic and Rhætic limestone. In the Gosau valley, near Halstatt, exposures are offered by a series of ravines; in the "Neue Welt" (south of Vienna, west of Wiener Neustadt) a number of coal-mines give the opportunity of following the succession of beds, although they are highly disturbed here; and I believe that the succession is not very different in the two valleys, notwithstanding their distance apart.

The base of the Gosau beds is formed by a calcareous breccia of variable thickness, evidently the consolidated débris of the surrounding mountains.

Then follows a series of freshwater beds, sandstones, marls and a few seams of coal, accompanied by freshwater Mollusca such as *Melanopsis*, *Dejanira*, *Boysia*, *Tanalia*, *Cyclas*, and *Unio*, and the remains of a highly heterogeneous flora, comprising a true Palm, together with *Pecopteris Zippi*, *Microzamia*, *Cunninghamites*, and leaves of a dicotyledonous tree resembling *Magnolia*, &c., evidently the mingling of the younger dicotyledonous type with a number of surviving older types. It is this horizon which has yielded the reptilian bones.

Deposits of a brackish character, with *Cerithium*, *Omphalia*, and *Actæonella*, begin to appear above the freshwater beds, sometimes apparently intercalated with them and accompanied by gravel beds and conglomerate, sometimes also by the first true marine strata, usually characterized by *Hippurites organisans* and *Nerinæa bicincta*.

The next group is formed by a loose marly limestone or a calcareous marl crammed with reef-building corals and with masses of *Hippurites cornu-vaccinum*, *Hipp. sulcatus*, *Caprina Aguilloni*, *Sphærulites organisans*, and a good number of highly ornamented Gasteropoda. This is the true French Turonian zone of *Hippurites cornu-vaccinum*.

This zone is succeeded by a series of loose grey and marly sandstones, likewise very fossiliferous. The reef-building corals and Rudistæ have disappeared or are very rare, corals being represented by a few species of *Cyclolites*, by *Diplochenium lunatum* and especially by *Trochosmilia complanata*. Here the first Ammonites appear. *Natica bulbiformis*, *Cardium productum*, *Protocardia Hillana*, *Trigonia limbata*, and *Janira quadricostata* are some of the most characteristic fossils.

In some places rose-coloured limestone beds with *Orbitoides* and the remains of a small Decapod are seen, which seem to succeed directly to this zone, which I have sometimes named the zone of *Trochosmilia complanata*.

The last and highest member of the Gosau beds is a series of sandy loose sandstone beds, containing no fossil except great numbers of *Inoceramus Crispii*.

I cannot, therefore, say positively that the age of the reptiles which you have had the kindness to study is quite exactly that of your Cambridge phosphate-beds; but it is certain that they are older than the true Turonian deposits, and especially older than the zone of *Hippurites cornu-vaccinum*.

EXPLANATION OF PLATES XXVII.–XXXI.

(All the figures are of the natural size, unless an enlargement is mentioned.)

Plate XXVII.

Fig. 1. Dentary bone of right ramus of lower jaw of *Mochlodon Suessii* (Bünzel) seen from above, showing tooth-sockets, symphysial curvature, and ascending coronoid process.

2. Separate tooth of *Mochlodon Suessii* from the lower jaw, showing the internal aspect; enlarged twice.

3. Tooth referred to the upper jaw of *Mochlodon Suessii,* showing the ribbed external face of the crown; enlarged twice.

4. Side view of the same tooth, showing the worn internal edge of the crown and curved fang.

5. Left side of hinder portion of skull of *Struthiosaurus austriacus* (drawn reversed for comparison with fig. 7), showing downward direction of occipital condyle, foramina at base of skull, plate in front of the sella turcica, transverse groove on roof of skull, &c.

6. The same skull seen from the front, showing the parieto-frontal suture, form of the parietal bone, cerebral cavity, form of the basisphenoid and sella turcica, &c.

7. Right side of hinder part of base of skull of *Acanthopholis horridus,* Huxley, showing the united basioccipital and basisphenoid bones, with the line of large nerve-foramina. (Original in Museum of Practical Geology.)

8. Anterior aspect of same specimen, showing posterior plate of sella turcica.

9. Dentary bone of right ramus of lower jaw referred to *Cratæomus.* The specimen is seen from above, and shows tooth-sockets along the alveolar margin.

10. External aspect of same specimen, showing the large foramina below the alveolar margin and above the longitudinal angle.

11. Tooth referred to *Cratæomus*, probably from the lower jaw, showing cinguloid ridge at the base of the crown; enlarged twice.

12. Similar tooth, less worn, showing serrations on the right margin; enlarged twice.

13. Tooth referred to the upper jaw of *Cratæomus*, showing bevelled edges, probably due to wear; enlarged twice.

14. External aspect of same specimen; enlarged twice.

15. Tooth probably of the larger species of *Cratæomus.*

16. Anterior aspect of same tooth, showing cinguloid thickening on both sides of the crown; enlarged twice.

17. Dorsal rib from the right side, referred to *Cratæomus lepidophorus,* showing articular surfaces.

18. Transverse section from the proximal third of the same rib, showing transverse expansion of the superior plate and lateral compression of the body of the rib.

19. Middle of shaft of left tibia referred to *Cratæomus lepidophorus,* showing muscular ridges on the fibular aspect and commencement of proximal expansion.

20. Proximal portion of right fibula of *Cratæomus*, showing convex tibial aspect.

21. Tooth referred to *Megalosaurus pannoniensis*; one and a half times natural size. [The serrations are not directed upward so much as in the figure.]

22. Anterior aspect of the same tooth, showing limit of the serrations.

23. Transverse section of base of same tooth, showing posterior compression.

24. Tooth of a Crocodile, with slight lateral ridges and worn crown; enlarged twice.

25. A smaller more compressed and curved Crocodilian tooth, showing one of the lateral ridges; enlarged twice.

26. Claw phalange, probably of *Rhadinosaurus.*

27. Internal surface of first left costal plate of *Emys Neumayri.*

Plate XXVIII.

Fig. 1. Proximal portion of left scapula, showing humeral articulation, probably referable to *Mochlodon Suessii.* [The articular surface is longer than in the figure.]
2. Dermal plate referred to *Cratæomus,* terminating at each end in a free spine.
3. Another dermal plate, with free spines at the ends and similar tubercles in the middle portion.
4. A dermal plate bearing a horn-like spine, also referred to *Cratæomus.*
5. A small scute referred to *Cratæomus,* probably from the ventral region.
6. Distal portion of right femur of *Ornithomerus gracilis,* showing part of the lateral trochanter on the inner side of the shaft.
7. Transverse section of the same bone at the proximal fracture, showing medullary cavity.
8. Right postfrontal bone of a Chelonian, seen from above, showing the cranial scutes, referred to *Pleuropeltus Suessii.*
9. Internal aspect of the same specimen, showing postorbital ridge and surfaces for union with adjacent bones.
10. Proximal end of right fibula of *Crocodilus proavus.*
11. Transverse section of the same bone at the distal fracture.

Plate XXIX.

Fig. 1. Superior aspect of left humerus of *Cratæomus lepidophorus.*
2. Inferior aspect of right humerus of the same species.
3. Proximal surface of left humerus, showing expansion of the radial crest.
4. Inferior aspect of distal end of a humerus referred to *Cratæomus Pawlowitschii.*
5. Transverse fracture of proximal end of the same specimen, showing medullary cavity.
6. Side view of claw-phalange of *Cratæomus.*
7. Internal aspect of proximal end of left femur of *Crocodilus proavus.*
8. Outline of proximal articular surface of the same specimen.
9. Ulna of *Crocodilus proavus.*
10. Proximal articular surface of the same specimen.
11. Radius of *Crocodilus proavus.*
12. Distal end of the same bone.
13. Proximal end of the same bone.

Plate XXX.

Fig. 1. Superior surface of parietal bone of a small Dinosaur, probably *Mochlodon Suessii.*
2. Side view of an angular truncated dorsal piece of dermal armour of *Cratæomus.*
3. Posterior aspect of dorsal vertebra of *Cratæomus Pawlowitschii,* showing transverse processes and fractured base of the neural spine.
4. Left side of early caudal vertebra of *Cratæomus Pawlowitschii.* [An earlier caudal exists with the short caudal rib unankylosed.]
5. Left side of dorsal vertebra of a Dinosaur, referred to *Cratæomus lepidophorus.*
6. Right side of mid cervical vertebra of *Crocodilus proavus.*
7. Anterior aspect of the same vertebra.
8. Posterior aspect of dorsal vertebra of *Crocodilus proavus.*
9. Left side of dorsal vertebra of *Crocodilus proavus.*
10. Anterior aspect of lumbar vertebra of *Crocodilus proavus.*
11. Left side of the same vertebra.
12. Left side of an early caudal vertebra of *Crocodilus proavus.*
13. Inferior aspect of the same vertebra.
14. Anterior aspect of the same vertebra.

Fig. 15. Side view of rib and part of superimposed plate, showing the rib free from the plate at the number 15, and the great expansion of the costal articulation at the other end. *Pleuropeltus Suessii.*

16. Right hyoplastral element of *Emys Neumayri.*

PLATE XXXI.

Fig. 1. Anterior aspect of shaft of right femur of *Cratæomus Pawlowitschii*, showing the muscular ridges.

2. Antero-external aspect of right tibia of *Cratæomus Pawlowitschii.*

3. Thin slightly keeled dermal plate, probably lateral, of *Cratæomus lepidophorus.*

4. Posterior and inferior aspect of left femur of *Cratæomus lepidophorus.* The figure 4 is placed opposite the small lateral trochanter.

5. Anterior and superior aspect of right femur of *Cratæomus lepidophorus.*

6. Posterior and inferior aspect of shaft of left femur of *Rhadinosaurus alcimus.* The figure 6 is placed against the lateral trochanter.

7. Outline of the proximal fracture of the same bone.

8. Antero-inferior aspect of shaft of left humerus referred to *Rhadinosaurus alcimus.*

9. Outline of proximal fracture of the same bone.

10. Outline of distal fracture of the same bone.

11. One of the flat dermal plates of *Hoplosaurus ischyrus*, showing the cross-fibre structure.

12. Proximal end of a rib of *Cratæomus Pawlowitschii*, for comparison with fig. 17, Pl. XXVII. Compare Bünzel, pl. iii. fig. 5.

13. Superior aspect of first costal plate of carapace of a Chelonian, *Emys Neumayri.*

Synopsis of the Bones figured in these Plates, arranged under the Species to which they are referred.

MOCHLODON SUESSII (Bünzel).

Dentary bone, Pl. XXVII. fig. 1; teeth, figs. 2–4; scapula, Pl. XXVIII. fig. 1; parietal bone, Pl. XXX. fig. 1.

STRUTHIOSAURUS AUSTRIACUS, Bünzel.

Hinder portion of skull, Pl. XXVII. figs. 5, 6.

ACANTHOPHOLIS HORRIDUS, Huxley.

Hinder portion of base of skull, Pl. XXVII. figs. 7, 8.

CRATÆOMUS (species uncertain).

Dentary bone, Pl. XXVII. figs. 9, 10; teeth, figs. 11–16.

CRATÆOMUS PAWLOWITSCHII, Seeley.

Femur, Pl. XXXI. fig. 1; tibia, fig. 2; fibula, Pl. XXVII. fig. 20; humerus, Pl. XXIX. figs. 4, 5; dorsal vertebra, Pl. XXX. fig. 3; caudal vertebra, fig. 4; dorsal rib, Pl. XXXI. fig. 12; dermal armour, Pl. XXVIII. figs. 2–4.

CRATÆOMUS LEPIDOPHORUS, Seeley.

Femur, Pl. XXXI. figs. 4, 5; tibia, Pl. XXVII. fig. 19; humerus, Pl. XXIX. figs. 1–3; dorsal vertebra, Pl. XXX. fig. 5; dorsal rib, Pl. XXVII. figs. 17, 18; claw-phalange, Pl. XXIX. fig. 6; dermal armour, Pl. XXX. fig. 2, Pl. XXXI. fig. 3, Pl. XXVIII. fig. 5.

HOPLOSAURUS ISCHYRUS, Seeley.

Dermal scute, Pl. XXXI. fig. 11.

MEGALOSAURUS PANNONIENSIS, Seeley.

Tooth, Pl. XXVII. figs. 21–23.

ORNITHOMERUS GRACILIS, Seeley.

Femur, Pl. XXVIII. figs. 6, 7.

RHADINOSAURUS ALCIMUS, Seeley.

Femur, Pl. XXXI. figs. 6, 7; humerus, figs. 8–10; claw-phalange, Pl. XXVII. fig. 26.

CROCODILUS PROAVUS, Seeley.

Vertebræ, Pl. XXX. figs. 6–14; femur, Pl. XXIX. figs. 7, 8; fibula, Pl. XXVIII. figs. 10, 11; ulna, Pl. XXIX. figs. 9, 10; radius, figs. 11–13; teeth, figs. 24, 25.

PLEUROPELTUS SUESSII, Seeley.

Postfrontal bone, Pl. XXVIII. figs. 8, 9; rib, Pl. XXX. fig. 15.

EMYS NEUMAYRI, Seeley.

Costal plate, Pl. XXVII. fig. 27; Pl. XXXI. fig. 13; hyoplastral plate, Pl. XXX. fig. 16.

The species described which are not figured are *Doratodon carcharidens*, Bünzel, *Oligosaurus adelus*, Seeley, *Aræosaurus gracilis*, Seeley, and *Ornithocheirus Bünzeli*, Seeley.

DISCUSSION.

Mr. HULKE considered Prof. Seeley's paper a very valuable communication, throwing, as it did, fresh light upon an important group of fossils the true nature of which had before been but imperfectly apprehended. So far as he had been able to judge from a cursory inspection of the fossils, he did not doubt the accuracy of Prof. Seeley's interpretations. He called attention to the anterior extremity of the mandible of *Mochlodon*, which had sutural indications of a prædentary ossification, such as he thought he had seen in *Hypsilophodon*; and he mentioned the difficulty which the downward extension of the Dinosaurian inner trochanter appeared to him to offer to the hypothesis of its homology with the human trochanter minor, an extension which suggested that it might rather be homologous with an outgrowth of the middle part of the linea aspera to which the short head of the biceps is attached.

Mr. CHARLESWORTH remarked on the difference between the teeth in the upper and lower jaw of *Mochlodon*.

Dr. MURIE pointed out that the work of Prof. Seeley showed that much caution must be exercised in accepting hurried descriptions of genera and species from fragments.

Prof. BOYD DAWKINS stated that his examination of the American collections of Secondary Saurians proved that the so-called Megalosaurian type of teeth was exhibited by forms belonging to very different genera.

The AUTHOR agreed with Prof. Dawkins's views concerning the Megalosaurian teeth, and agreed that teeth were not sufficient alone for generic determinations.

43. *On the* Occurrence *of the Remains of a* Cetacean *in the* Lower Oligocene *Strata of the* Hampshire Basin. By Prof. John W. Judd, F.R.S., Sec. G.S.; *with an* Appendix *by* Prof. Seeley, F.R.S., F.G.S. (Read June 22, 1881.)

Remains of the marine mammalia have been so seldom recorded from the Lower Tertiaries of Britain, that the discovery of a new form is of considerable interest to the geologist. Up to the present time the only species noticed was the *Zeuglodon Wanklyni*, described by Prof. Seeley* in 1876. The remains of this species, which were found in the Barton Clay, would appear to have been unfortunately lost. The form which I have now the honour of laying before the Society is represented by a caudal vertebra only; but this appears to present some very interesting peculiarities.

The locality from which this specimen was obtained is Roydon, about a mile and a half south of Brockenhurst, in the New Forest. The brickyard at this place is almost the only locality in the New Forest at which the very interesting marine fauna of the Brockenhurst Series can now be collected. The beds exposed at this brickyard consist of sandy clays crowded with marine fossils; they have been exposed to the depth of 25 feet; but as no overlying freshwater beds have been seen in conjunction with them, the total thickness of the Brockenhurst Series cannot be determined. Judging, however, from the wide area over which the beds of this age have been found to be exposed, that thickness must be considerable. These thick marine strata are seen at Roydon to rest directly upon freshwater clays of a bright green colour and crowded with specimens of *Unio Solandri*, Sow., which doubtless belong to the Headon Series.

That the Roydon beds belong to the same great marine series as the beds of Brockenhurst and Lyndhurst appears to be clearly proved by a comparison of the abundant fossils from the three localities. On this point Von Könen and the late Mr. F. Edwards, who collected so assiduously at all those places, appear to have entertained no doubt whatever. Recently, however, an attempt has been made to separate the Roydon beds into two formations, and to assign each of these and the Brockenhurst beds to different geological horizons †, on the ground that certain forms which are rare at one locality are abundant at the others, and *vice versâ*. The fauna of all these beds is so unmistakably that of the Lower Oligocene or Tongrian that it is impossible to find any valid grounds for such a subdivision.

Terrestrial mammalia are so abundant in the overlying Bembridge beds, as well as in the underlying Headons, that the discovery of this marine form in the Brockenhurst Series is of much

* Quart. Journ. Geol. Soc. vol. xxxii. p. 428, 1876.

† Quart. Journ. Geol. Soc. vol. xxxvii. p. 113.

interest, affording, as it does, such an important confirmation of the conclusion that a great change in the physical conditions of the area must have occurred at the time when these marine strata were deposited.

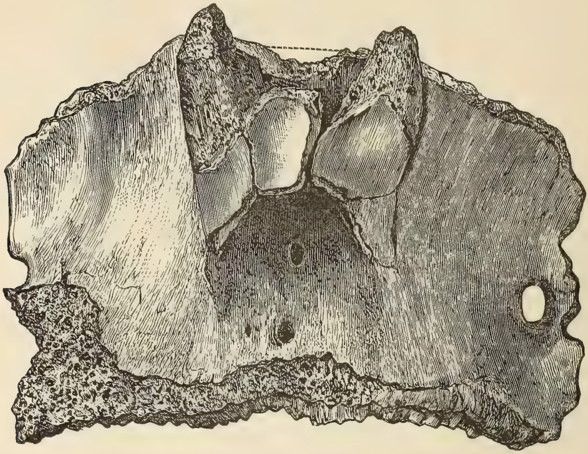
APPENDIX.

Note on the CAUDAL VERTEBRA *of a* CETACEAN *discovered by* Prof. JUDD *in the* BROCKENHURST *beds, indicative of a* NEW TYPE *allied to* BALÆNOPTERA (BALÆNOPTERA JUDDI). By Prof. H. G. SEELEY, F.R.S., F.G.S.

THE vertebra submitted to me by Professor Judd belongs to the caudal region; and although in a new type there may be some doubt concerning the exact place in the series, it may be affirmed to have been about the eighth caudal, and certainly not later than the twelfth. The vertebra is probably distinct from all recent and fossil genera; but its characters are altogether in harmony with the Balænidæ; and the specimen indicates a genus much more closely related to *Balœnoptera* than to *Balœna*, so far as can be judged from a single vertebra. This affinity is especially shown in the character of the base of the centrum, which had the facets for the chevron bones very small, and also in the general character of the neural arch, which is much less massive than in *Balœna*. The differences from the great *Balœnoptera musculus* on the other hand are clearly defined, and appear to consist in the remarkably forward position of the neural arch (fig. 2), since in *Balœnoptera* it does not usually reach the anterior sutural margin. The depressed transversely ovate outline of the neural canal (fig. 3) is another distinctive character, since in *Balœnoptera* the neural canal is higher than wide. The neural spine also appears to be much less developed than in the recent genus, though, as the hinder part of the neural arch is broken away, this character cannot be positively affirmed. The centrum is relatively much shorter (fig. 2); the facets and ridges on the base connected with the chevron bones are less developed. The transverse width of the zygapophyses was relatively greater in the fossil. The transverse process is remarkable for extending the entire width of the centrum (fig. 2), and for having the vertical perforation rather behind the middle of the centrum (fig. 1), since in *Balœnoptera* it is placed further forward. *Balœnoptera laticeps*, however, a species of the North Sea, ranging, perhaps, to Java and Japan, approaches nearer to the fossil, especially in having the epiphyses separate; the neural arch, too, is placed almost as far forward as in the fossil, but is higher, and the neural spine is larger; but otherwise its characters are very similar. Perhaps when we reflect that the contemporaries of this old whale were *Palœotherium*, *Anoplotherium*, and their allies and congeners, all of which have passed away, it will not seem improbable that the marine mammals also should give evidence of subgeneric differences.

Fig. 1.—*Caudal Vertebra of* Balænoptera Juddi, *seen from above.*

Anterior border.



Posterior border.

[The vertebra does not lean forward as represented in the figure.]

Fig. 2.—*Right side of eighth* (?) *Caudal Vertebra of* Balænoptera Juddi, *showing anterior position of the neural arch and vertical perforation of the transverse process.*

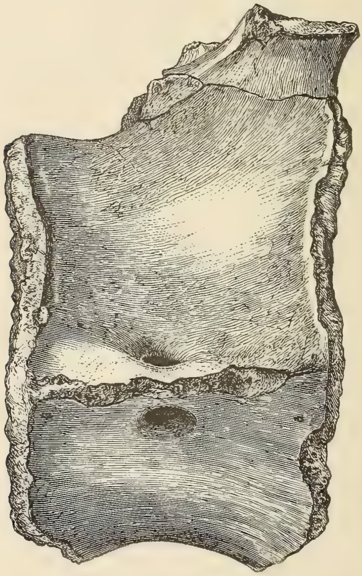
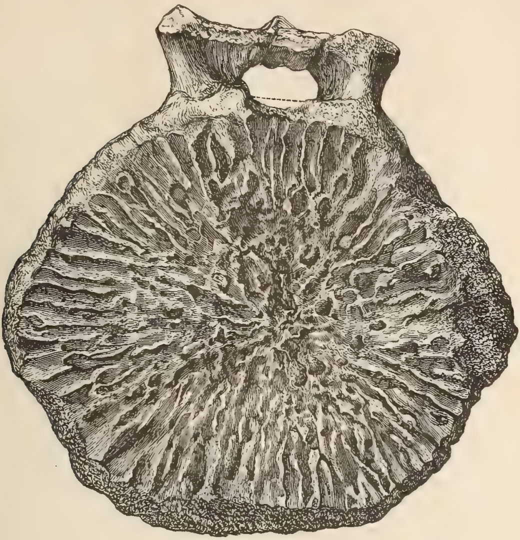


Fig. 3.—*Anterior Aspect of Caudal Vertebræ of* Balænoptera Juddi, *showing the depressed form of the neural arch and sutural surface, from which the vertebral epiphysis has come away.*



A tail vertebra of a whale, however, is about the last thing which an anatomist would select to furnish characters for a new genus. I have not thought that attention is more likely to be called to the fossil by thus dealing with it than would be the case by adopting the safer course of shrinking from the responsibility of indicating a genus which could not at present be sustained.

The centrum has lost its epiphyses (fig. 3); each end is hexagonal, and marked with the usual radiating longitudinal rugosities. The centrum is longer at the superior margin, which measures nearly 7 centim., than at the inferior margin, where the measurement is 6·2 centim.; so that there is a conspicuous leaning forward of the superior margin of the vertebra (fig. 2). Among vertebrates this character recalls a characteristic condition of the vertebræ of *Pliosaurus*. As already remarked, the face of the centrum is hexagonal; it is 10·2 centim. wide, and 8·7 centim. deep. The superior surface of the centrum is short, since the transverse outside measurement of the neural arch is only 4 centim.; and the width of the base of the centrum is probably no more, though its anterior and posterior margins are abraded, so that the exact characters cannot be stated. The lateral surfaces are unequally divided by the transverse processes (fig. 3), the superior pair, 5·3 centim. long, being the longest. Their margins are moderately convex; the inferior lateral borders were under 5 centim. long. The posterior surface of the centrum is broken on the superior, inferior, and left lateral margins. The lateral margins appear to have been more convex behind than in front, and the transverse width of the centrum appears to have been greater, about 10·6 centim. The base of the centrum is narrow, with a median longitudinal depression more marked beneath than in front, but not very conspicuous, and yet sufficient to give the base the appearance of being formed of two rounded lateral portions. The basal surface is concave from front to back: it is impossible to state its transverse width in the middle, because there are no lateral limiting lines; but it exceeds $2\frac{1}{2}$ centim. The inferior lateral surfaces are nearly flat from above downward, the concavity being scarcely appreciable, but are markedly concave from front to back. The superior lateral surfaces are convex from above downwards (fig. 2), the convexity being least marked in the middle and more marked on the posterior border than on the anterior border. The length of the transverse processes cannot be given, because they are fractured; but since the fractured end is only half a centim. thick, and 4·7 centim. wide, it was presumably short. This process is perforated vertically by an oval foramen (fig. 1) which is 7 millim. long and 5 millim. wide. Its anterior margin is distant 3·4 centim. from the anterior border of the vertebra; and the posterior margin is 2·5 centim. from the posterior border. On the left side the foramen appears to be a little smaller, and nearer to the middle of the centrum.

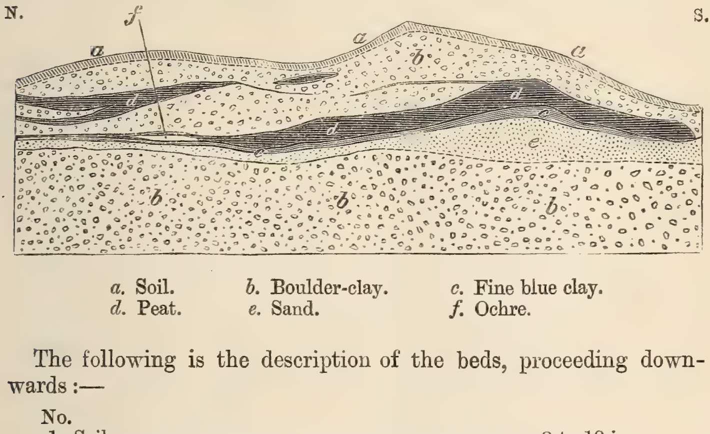
The neural arch is small, depressed, placed anteriorly so as somewhat to overhang the centrum (fig. 1). It has a scarcely appreciable neural spine (fig. 2); but its posterior margin is broken away. The sides of the neural arch converge posteriorly, so that the transverse measurement behind, as preserved, is 3 centim. The antero-posterior measurement of the base of the neural arch is rather more than 4 centim. (fig. 2). The anterior zygapophyses, if such existed, are broken away; and the extreme transverse width of the neural arch in front (fig. 3), which is obviously less than its width when perfect, is about 5 centim. The sides of the arch are directed upward and outward; and the neurapophyses are compressed. The canal for the spinal cord is wider in front than behind, and higher behind than in front. The transverse measurement in front is 2·7 centim. The height in front is 1·4 centim. The height behind is about 1·6, as preserved, and the width fully 2 centim. The neural canal is concave from front to back, and contains several nutritive foramina. Two are placed near to the anterior margin, and one in the middle line behind the middle of the centrum. The superior surface of the neural arch was probably notched in front, where it was concave from side to side; it was inclined backward, where the sides converge, and where it is divided mesially by the faint indication of a neural spine (fig. 1).

44. *Description of a* Peat Bed *interstratified with the* Boulder-Drift *at* Oldham. By Geo. H. Hollingworth, Esq., F.G.S. (Read June 22, 1881.)

In the early part of September last Mr. James Nield, of Oldham, called my attention to a bed of peat which he had discovered on the site of the railway-extensions then being made by the London and North-Western Railway Co., at Rhodes Bank, Oldham.

The length of the section exposed to view was 53 feet in a north-to-south direction, and the maximum depth 14 feet; but the depth of the drift, as proved at the colliery about 100 yards to the west, is $34\frac{1}{2}$ feet.

Section of Boulder-clay with interstratified Peat, near Rhodes Bank, Oldham. (Scale about 14 feet to 1 inch.)



a. Soil. *b.* Boulder-clay. *c.* Fine blue clay.
d. Peat. *e.* Sand. *f.* Ochre.

The following is the description of the beds, proceeding downwards:—

No.		
1.	Soil	8 to 10 in.
2.	Boulder-clay, sometimes sandy, with beds and strings of peat	2 to 6 ft.
3.	Main bed of peat containing mosses, exogenous stems, and beetles. At one point there was enclosed in the peat a deposit of iron ochre (*f*) about 6 inches in maximum thickness and 6 feet long...	2 in. to 1 ft. 9 in. Average 15 in.
4.	Blue clay, mostly very fine, but stony where thickest, forms the floor clay or soil	2 in. to 1 ft.
5.	Current-bedded coarse sand and fine gravel, red- and yellow-coloured	4 in. to 2 ft.
6.	Boulder-clay, proved	6 ft.

The deposit is situate in the valley of the Medlock, about 25 feet above its present level; but it has not beeen exposed by that brook, at this point, where there is from 2 to 6 feet of the upper clay still resting upon the peat. The upper clay, peat, and lower clay have probably been denuded by the action of the brook some yards to the west. The upper clay is continuous to the east for at least 200 yards, and was proved to be about 4 feet thick for 15 yards to the east of the section by the operations of the Railway Company in search of sand. At that point the sand was more than 6 feet in thickness, the bed of peat having run out. The boulders are mostly from a distance (porphyries, granites, &c.); but a few are of local origin, one picked up being ganister from the lower coal-measures.

The section, which is now covered up, was measured by me when about 6 yards of the strata had been excavated from the face at right angles to the section.

The peat bed terminates on the right of the section; but on the left or north the upper bed is going forward. The floor clay (4) is of a fine silty nature generally, and is very similar to the floor clay of the Ashton Moss (Ashton-under-Lyne) as exposed in the railway-cutting.

The mosses &c. have been placed in the hands of the Rev. J. Ferguson, of Brechin, N. B., for examination; but his final report has not yet been received. They are, however, of decidedly northern character.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described; and those of which the names are printed in italics are also figured.]

END OF VOL. XXXVII.

Printed by Taylor and Francis, Red Lion Court, Fleet Street.

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1880–81.

November 3, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Bernard Barham Woodward, Esq., 19 Stowe Road, Shepherd's Bush, W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following specimens were presented to the Museum:—

Twenty specimens of Carboniferous Limestone Fossils from Flathead River, Rocky Mountains (49th Parallel N.W. America), presented by H. Bauerman, Esq., F.G.S.

The President announced that the original portrait of Dr. William Smith, painted by M. Fourau in the year 1837, had been presented to the Society by William Smith, Esq., of Cheltenham.

The following communications were read:—

1. "On the Serpentine and Associated Rocks of Anglesey, with a Note on the so-called Serpentine of Porthdinlleyn (Caernarvonshire)." By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

2. "Note on the Occurrence of Remains of Recent Plants in Brown Iron-ore." By J. Arthur Phillips, Esq., F.G.S.

3. "Notes on the Locality of some Fossils found in the Carboniferous Rocks at T'ang Shan, situated, in a N.N.E. direction, about 120 miles from Tientsin, in the province of Chih Li, China." By

James W. Carrall, Esq., F,G.S. With a Note by Wm. Carruthers, Esq., F.R.S., F.G.S.

The following specimens were exhibited:—

Rock-sections and specimens of rocks from Anglesey and Porthdinlleyn, exhibited by Prof. T. G. Bonney in illustration of his paper.

Remains of recent plants in brown iron-ore, exhibited by J. Arthur Phillips, Esq., in illustration of his paper.

Carboniferous plant-remains, from T'ang Shan, Chih Li, China, exhibited by J. W. Carrall, Esq., in illustration of his paper.

Sections of Devonian Corals, Agates, and Mocha Stones, exhibited by S. H. Needham, Esq., to illustrate a new method of mounting large sections of fossils, and minerals, and other natural-history objects (such as Lepidoptera), so as to exhibit both the upper and under surfaces at one view.

November 17, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Prof. Joseph Henry Tompson, of the Auckland College, Auckland, New Zealand, was elected a Fellow of the Society.

The names of the following Fellows in arrear to the Society were read out by the President for the first time, in accordance with Section VI. B, Article 6, of the Bye-laws:—W. H. Peacock, Esq., and W. Salmon, Esq.

The List of Donations to the Library was read.

The President called attention to the portrait of Dr. William Smith, presented to the Society by his grand-nephew, Mr. W. Smith, of Cheltenham, which was then suspended behind the chair, and expressed his great satisfaction at this most interesting picture being in the possession of the Society.

Mr. W. W. Smyth expressed the satisfaction that all must feel in possessing a genuine relic of this eminent stratigraphical geologist. Now this one, which had been so liberally presented to the Society, was a most indubitable portrait of the most conspicuous founder of English geology. That portrait was painted by M. Fourau in 1837, and was certainly an admirable likeness. The Society was deeply indebted to the donor, Mr. W. Smith, the cousin of the late valued Prof. Phillips. The portrait now hanging on the wall was engraved in Prof. Phillips's 'Life' of his uncle. He proposed a hearty vote of thanks to the donor.

Mr. Evans rose with great pleasure to second the vote of thanks proposed by Mr. Warington Smyth. The portrait was indeed replete with interest, not only to English geologists but to all geologists in the world. An additional interest attaching to the portrait was that we had the whole history of it from Dr. Smith's own hand, an extract from which Mr. Evans read. The portrait was an admirable one. He hoped that in the future Mr. Smith's example would be followed, and that we should see many other portraits of eminent geologists on the Society's walls. The Society was also deeply indebted to the President for the interest which he had taken in the matter.

The vote of thanks was carried by acclamation.

The following communications were read :—

1. "On abnormal Geological Deposits in the Bristol District." By Charles Moore, Esq., F.G.S.

2. "Interglacial Deposits of West Cumberland and North Lancashire." By J. D. Kendall, Esq., C.E., F.G.S.

Specimens from deposits in the Bristol District were exhibited by Mr. Moore in illustration of his paper.

December 1, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

William Heward Bell, Esq., East Shefford House, Hungerford; William Jackson, Esq., Vernon Terrace Schools, Northampton; Peregrine Propert Lewes, Esq., M.A., L.L.M., 84 Kensington Gardens Square, W.; William Libbey, Esq., Jun., M.A., D.Sc., Princeton College, Princeton, New Jersey, U.S.A.; David Morgan Llewellin, Esq., Bryn Gomer, near Pontypool, Monmouthshire; John Marshall, Esq., Sowerby Bridge, near Halifax; Cyril Parkinson, Esq., Rock Cottage, Ventnor, Isle of Wight, and Farnsfield, Southwell, Notts; Cornelius McLeod Percy, Esq., The Grove, Standish, Wigan; Thomas John Robinson, Esq., Melbourne Street, Longton, Stoke-on-Trent; Rev. Alfred Rose, M.A., Emmanuel College, Cambridge; Beeby Thompson, Esq., F.C.S., Abington Street, Northampton; and Stuart Crawford Wardell, Esq., Doe Hill House, Alfreton, Derbyshire, were elected Fellows of the Society.

The names of the following Fellows in arrear to the Society were read out by the President for the second time, in accordance with

Section VI. B, Article 6, of the Bye-laws:—W. H. Peacock, Esq., and W. Salmon, Esq.

The List of Donations to the Library was read.

The following communications were read :—

1. "On Remains of a small Lizard from the Neocomian Rocks of Comén, near Trieste, preserved in the Geological Museum of the University of Vienna." By Prof. H. G. Seeley, F.R.S., F.G.S.

2. "On the Beds at Headon Hill and Colwell Bay in the Isle of Wight." By H. Keeping, Esq., and E. B. Tawney, Esq., M.A., F.G.S.

Specimens were exhibited by Prof. Seeley and Messrs. Tawney and Keeping in illustration of their papers.

December 15, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

William Elijah Benton, Esq., Assoc. R.S.M., Highfield House, Heather, near Ashby-de-la-Zouch; Rev. George Clements, 26 St. Martin's Road, Stockwell; J. Kerr Gulland, Esq., C.E., 6 A Victoria Street, S.W., and Ball's Pond Road, N.; Francis T. S. Houghton, Esq., B.A., Wynnstay, Balsall Heath, Birmingham; George Bingley Luke, Esq., Northbank House, Prestonpans, N.B.; and William Mansell MacCulloch, Esq., MD., 12 Cork Street, Burlington Gardens, W., were elected Fellows; and Professor Luigi Bellardi, of Turin, and Dr. M. Neumayr, of Vienna, Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "On the Constitution and History of Grits and Sandstones." By John Arthur Phillips, Esq., F.G.S.

The Chair was then taken by J. W. Hulke, Esq., F.R.S., V.P.G.S.

2. "On a New Species of *Trigonia* from the Purbeck Beds of the Vale of Wardour." By R. Etheridge, Esq., F.R.S., President. With a Note on the Stratigraphical position of the Fossil by the Rev. W. R. Andrews.

The following specimens were exhibited :—

Specimens exhibited by Messrs. J. Arthur Phillips and R. Etheridge in illustration of their papers.

Specimens of Crinoids from the Carboniferous Limestone, and a pair of candlesticks turned out of Carboniferous Limestone, exhibited by Prof. James Tennant, F.G.S.

January 5, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

George C. Crick, Esq., 9 Gwyn Street, Bedford; and Arthur S. Reid, Esq., B.A., 12 Bridge Street, Canterbury, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "The Archæan Geology of Anglesey." By C. Callaway, Esq., M.A., D.Sc., F.G.S. With a Note on the Microscopic Structure of some of the Rocks, by Prof. T. G. Bonney, M.A., F.R.S., Sec.G.S.

2. "The Limestone of Durness and Assynt." By C. Callaway, Esq., D.Sc., F.G.S.

3. "On a Boulder of Hornblende-Picrite near Pen-y-Carnisiog, Anglesey. By Prof. T. G. Bonney, M.A., F.R.S., Sec.G.S.

The following specimens were exhibited :—

Specimens of the results of some experiments in the formation of Agates &c. exhibited by E. A. Pankhurst, Esq., and James I'Anson, Esq., F.G.S.

Rock-specimens and microscopic sections exhibited by Dr. Callaway and Prof. Bonney, in illustration of their papers.

January 19, 1881.

Robert Etheridge, Esq., F.R.S., President in the Chair.

Jabez Church, Esq., M.Inst.C.E., 17B Great George Street, Westminster, S.W.; George Augustus Freeman, Esq., B.Sc. Lond., 6

Macduff Terrace, Danby Street, Peckham, S.E.; Charles Horsley, Esq., C.E., 174 Highbury New Park, N.; Edwin Simpson-Baikie, Esq., F.L.S., United University Club, Pall Mall East, S.W.; and Charles John Wood, Esq., M.Inst.C.E., 2 Selbourne Terrace, Bradford, Yorkshire, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President called attention to the valuable donation made to the Library by Dr. J. J. Bigsby, F.R.S., F.G.S., of the set of six volumes of the 'Reports of the Geological Survey of Illinois,' the last four volumes of which are extremely rare on this side of the Atlantic, if not almost unique. A special vote of thanks was passed to Dr. Bigsby for his present.

The following communications were read:—

1. "Further Notes on the Family Diastoporidæ, Busk." By G. R. Vine, Esq. Communicated by Prof. P. Martin Duncan, M.B.Lond., F.R.S., F.G.S.

2. "Further Notes on the Carboniferous Fenestellidæ." By G. W. Shrubsole, Esq., F.G.S.

The following specimens were exhibited:—

Specimens of Opal, Chalcedony, &c., from Australia, exhibited by Prof. James Tennant, F.G.S.

Specimens of Fenestellidæ, exhibited by Mr. Shrubsole in illustration of his paper.

February 2, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Joseph Groves, Esq., B.A., M.B.Lond., Carisbrooke, Isle of Wight; George Lewis, Esq., Green Hill, Derby; Rev. Edouard Méchin, S.J., St. Beuno's College, St. Asaph, North Wales; James Osborne, Esq., Rio Tinto, Province of Huelva, Spain; and the Rev. William Sharman, 20 Headland, Plymouth, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Coralliferous Series of Sind, and its connexion with the last Upheaval of the Himalayas." By Prof. P. Martin Duncan, M.B.Lond., F.R.S., F.G.S.

2. "On two new Crinoids from the Upper Chalk of Southern Sweden." By P. H. Carpenter, Esq., M.A. Communicated by Prof. P. Martin Duncan, M.B.Lond., F.R.S., F.G.S.

The following specimens were exhibited :—

A specimen of a new Crinoid, exhibited by Mr. Carpenter in illustration of his paper.

Microscopic sections of Meteorites, exhibited by Dr. Otto Hahn, of Reutlingen.

In explanation of the latter the following remarks were addressed on behalf of Dr. Hahn to the President and Fellows present :—

"Dr. Hahn, in inviting you to examine the microscopical specimens of meteorites which he has prepared, and in order to assist you in determining the character of the forms and structures which you will find exhibited in them, desires to present a short summary of the negative considerations which forbid that such structures should be classed among crystalline forms.

"As is well known, the chondrites, the species of meteorites from which his specimens are prepared, consist, besides the metals which they enclose, of the minerals enstatite and olivine.

"In his work on the meteorites and their organisms, lately published, Dr. Hahn has given photographs of 130 different forms and structures. Now if these structures are crystalline, the two minerals in question would present themselves in at least 130 different forms and structures, although the absence of all structure is recognized as a fundamental principle of the theory of minerals.

"Again, the structures exhibited by the chondrites cannot be due to slaty cleavage, since olivine has no slaty cleavage, and that of enstatite and of other minerals does not appear under the microscope, or else presents itself there under totally different forms.

"The greatest importance, however, is to be attached to the total absence of all polarized light exhibited by the two minerals as occurring in the meteorites. The contained forms and structures do not polarize the light at all, or only very feebly, although the same minerals, under ordinary circumstances, polarize light very strongly. The absence of all aggregate polarization is especially noticeable, as proving that these objects are not aggregates of crystals.

"Should we still feel inclined to regard the enclosures as mineral forms, and not as organisms, we must be struck by the utter absence of all crystalline forms, especially in those very minerals which always, and occasionally also in meteorites, appear in a crystallized form.

"Further, the external forms, and consequently the outlines of the enclosures, harmonize so perfectly with their internal form and structure, that we cannot entertain the idea that these enclosures had been rolled about and ground down before they became finally imbedded in the chondrites.

"The idea of an aggregate of crystals, if still looked upon with favour, would be contradicted by the fact that the enclosed balls or globes are all constructed excentrically, whereas all terrestrial crystallites are formed concentrically."

ANNUAL GENERAL MEETING,

February 18, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Report of the Council for 1880.

In presenting their Report for the year 1880, the Council of the Geological Society have much gratification in announcing to the Fellows that the affairs of the Society are in a much more satisfactory position than at the dates of their last two Reports.

The number of new Fellows elected during the year is 60, of whom 49 paid their fees before the end of the year, making, with 14 previously elected Fellows who paid their fees in 1880, a total accession during the year of 63 Fellows. Against this we have to record the loss by death of 34 Fellows, and by resignation of only 9 Fellows, whilst 5 Fellows were removed from the list for nonpayment of Contributions, making a total loss of 48 Fellows. On the year, therefore, we have an increase of 15 Fellows. But as of the 34 Fellows deceased, 9 were compounders, and 9 con-contributing Fellows, the number of contributing Fellows is actually increased by 25, being now 769.

The total number of Fellows and Foreign Members and Correspondents was 1415 at the end of the year 1879, and 1432 at the end of the year 1880.

During the year 1880 intelligence was received of the death of 1 Foreign Member and of 2 Foreign Correspondents. As two vacancies existed in the list of Foreign Members at the end of the year 1879, three Foreign Members were elected in 1880; and the vacancies caused by these elections and by death in the list of Foreign Correspondents, were all filled up during the year.

The total Receipts for the year 1880 were £2706 1*s.* 7*d.*, being £130 15*s.* 7*d.* more than the estimated Income for the year. The total Expenditure, on the other hand, was £2520 18*s.* 9*d.*, or £154 4*s.* 1*d.* less than the estimate for the year. The actual excess of Income over Expenditure was thus £185 2*s.* 10*d.*; and of this amount a sum of £98 10*s.* was invested in the purchase of £100 Consols.

The Council have to announce the completion of Vol. XXXVI. of the Quarterly Journal and the commencement of Vol. XXXVII.

The Council have further to announce the completion of the printing of the Catalogue of the Library, which is now ready for distribution to subscribers. It forms a volume of over 620 pages, or about 100 pages more than was originally estimated; but the Council have not thought it desirable to increase the price of the volume. It will accordingly be furnished to the Fellows at the price of five shillings.

The Council have much pleasure in announcing that William Smith, Esq., of Cheltenham, the grandnephew of Dr. William Smith, and cousin of the late Professor Phillips, has most liberally presented to the Society the portrait of Dr. Smith which was formerly in Prof. Phillips's possession, and from which was engraved the small portrait illustrating his 'Memoir of William Smith.' This picture, which is admirable in itself, is of special interest to the Fellows of the Geological Society, not only as an excellent portrait of one of the great founders of their Science, but also from its historical associations, as its origin and mode of production have been described in Dr. Smith's own words in the 'Memoir' just mentioned, as it bears his handwriting on its back, and as it is the original of the engraved portrait. For the due preservation of this valuable picture the Council have ordered it to be suitably framed and covered with plate glass, and to be suspended in a place of honour in the Meeting-room of the Society. They hope that it may not long remain there in solitude. In the mean-time four of the marble busts in the possession of the Society (those, namely, of Greenough, Sedgwick, Murchison, and Macculloch) have been arranged upon pedestals at the end of the Meeting-room, where they may serve to cherish the memory of some of those who have contributed the most to advance the Science of Geology.

The Council have awarded the Wollaston Medal to Professor P. Martin Duncan, F.R.S., F.G.S., in testimony of their high appreciation of his numerous and valuable palæontological memoirs, especially on the Fossil Corals, as well as of his contributions to physical and stratigraphical Geology.

The Murchison Medal, with the sum of Ten Guineas from the proceeds of the Fund, has been awarded to Professor Archibald Geikie, F.R.S., F.G.S., in recognition of his valuable contributions to physical and stratigraphical Geology, particularly in relation to the Old Red Sandstone of Scotland, and the Volcanic Geology of the vicinity of Edinburgh and the Firth of Forth.

The Lyell Medal, with a sum of Twenty-five Pounds from the proceeds of the Fund, has been awarded to Principal Dawson, F.R.S., F.G.S., in recognition of his important contributions to the Geology of Canada, and more especially of his investigations into the Fossil Flora of the Devonian and Carboniferous Periods in America.

The Bigsby Medal has been awarded to Dr. Charles Barrois, of Lille, as a testimony to the importance of his contributions to stratigraphical Geology, particularly with relation to the Cretaceous system.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to Dr. Ramsay H. Traquair, F.G.S., in recognition of the value of his researches upon the palæontology of Fossil Fishes, and to aid him in pursuing his investigations.

The balance of the proceeds of the Murchison Donation Fund has been awarded to Frank Rutley, Esq., F.G.S., as a token of appreciation of his valuable memoirs on various petrological subjects, and to assist him in carrying on his researches.

The balance of the proceeds of the Lyell Donation Fund has been awarded in equal parts to G. R. Vine, Esq., in recognition of the work done by him on the Carboniferous Polyzoa, and to assist him in continuing his investigations; and to Dr. Anton Fritsch, of Prague, as a mark of the estimation in which his valuable contributions to Palæontology are held, and to aid him in the production of his important memoirs.

During the last Session, a subscription was set on foot among the Fellows of the Society, which enabled the Assistant Secretary to purchase four small plain Microscopes, for use, when required, at the Evening Meetings of the Society. As the procuring the means of illumination for the microscopes was attended with considerable inconvenience and expense, the Council have decided to expend a small portion of the proceeds of the Barlow-Jameson Fund in the purchase of four of How's Microscope Lamps.

Report of the Library and Museum Committee.

Library.

Since the last Anniversary Meeting a great number of valuable additions have been made to the Library, both by donation and by purchase.

As Donations the Library has received 105 volumes of separately published works and Survey Reports, and about 220 Pamphlets and separate impressions of Memoirs; also about 102 volumes and 205 detached parts of the publications of various Societies, and 14 volumes of independent Periodicals presented chiefly by their respective Editors, besides 11 volumes of Newspapers of various kinds. This will constitute a total addition to the Society's Library, by donation, of about 272 volumes and 220 pamphlets.

A considerable number of Maps, Plans, and Sections have been added to the Society's collections by presentation from various Geological Surveys, from the Ordnance Survey of Great Britain, and from the French Dépôt de la Marine. Several Geological Maps of particular districts have also been presented by the authors. They amount altogether to 348 sheets, and among them may be noted, as especially valuable to the Society, 131 sheets of the Map of the Geological Survey of Great Britain and Ireland.

The Books and Maps just referred to have been received from

128 personal Donors, the Editors or Publishers of 15 Periodicals, and 131 Societies, Surveys, or other Public Bodies, making in all 274 Donors.

By Purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 46 volumes of Books, and of 53 parts (making about 10 volumes) of Periodicals, besides 12 parts of works published serially, the earlier portions of which were obtained in previous years. Five Sheets of the Geological Survey Map of France, and 4 sheets of a Map of the Bohemian Coalfield, by Dr. Wolff, have been obtained by purchase.

The cost of Books and Periodicals during the year 1880 was £73 2*s*. 3*d*., and of Binding £76 10*s*. 1*d*. The total expenditure on account of the Library was thus £149 12*s*. 4*d*.

The Books in the Society's Library are generally in good condition; and a considerable number of old serial and other works, of which the binding had been damaged by long use, have been rebound or repaired. The Library continues to be much used by the Fellows of the Society.

Museum.

The Collections in the Museum remain in much the same condition as at the date of the last Report of the Committee, the Foreign Collections being all available for reference. The Egerton Collection of Arctic Fossil Shells has been named and arranged by Dr. J. Gwyn Jeffreys.

The following Donations have been made to the Museum during the year 1880;—A specimen of rock from the top of the Asnai Heights, Cabul, presented by Lieut. F. Spratt, R.E., and 20 specimens of Carboniferous-limestone Fossils from Flathead River, Rocky Mountains, presented by H. Bauerman, Esq., F.G.S.

Comparative Statement of the Number of the Society at the close of the years 1879 and 1880.

	Dec. 31, 1879.		Dec. 31, 1880.
Compounders	313	......	312
Contributing Fellows.....	744	......	769
Non-contributing Fellows..	277	......	268
	1334		1349
Honorary Members	3	......	3
Foreign Members	38	......	40
Foreign Correspondents....	40	......	40
	1415		1432

General Statement explanatory of the Alterations in the Number of Fellows, Honorary Members, &c. at the close of the years 1879 *and* 1880.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1879			1334
Add Fellows elected during former year and paid in 1880			14
Add Fellows elected and paid in 1880			49
			1397
Deduct Compounders deceased		9	
Contributing Fellows deceased		16	
Non-contributing Fellows deceased		9	
Contributing Fellows resigned		9	
Contributing Fellows removed		5	
		—	48
			1349
Number of Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1879		81	
Deduct Foreign Member deceased	1		
Foreign Correspondents deceased ..	2		
Foreign Correspondents elected Foreign Members	3		
	—	6	
		75	
Add Foreign Members elected	3		
Foreign Correspondents elected	5		
	—	8	
		—	83
			1432

Deceased Fellows.

Compounders (9).

Lord Belper.
T. Bell, Esq.
Col. W. G. Boyle.
Sir R. Burdett.
W. W. Collins, Esq.
W. Gillespie, Esq.
W. H. Holloway, Esq.
E. Walton, Esq.
S. V. Wood, Esq.

Resident and other Contributing Fellows (16).

Prof. D. T. Ansted.
T. D. Bott, Esq.
Lieut.-Gen. W. E. D. Broughton.
E. W. Cooke, Esq.
J. Cope, Esq.
J. G. H. Godfrey, Esq.
J. Hamilton, Esq.
W. G. Kell, Esq.
D. Llewellin, Esq.
H. Ludlam, Esq.
Dr. E. Meryon.
E. J. Smith, Esq.
T. Parry, Esq.
W. W. Stoddart, Esq.
Rev. J. Clifton Ward.
E. B. Webb, Esq.

Non-contributing Fellows (9).

C. L. Bradley, Esq.
R. Davey, Esq.
T. C. Eyton, Esq.
W. Gray, Esq.
Very Rev. H. P. Hamilton.
J. R. Logan, Esq.
Rev. S. Lucas.
Prof. W. H. Miller.
Dr. Jones Quain.

Foreign Member.

Prof. P. H. Nyst.

Foreign Correspondents.

Prof. W. P. Schimper.
M. J. A. H. Bosquet.

Fellows Resigned (9).

Rev. W. H. Allen.
F. Campion, Esq.
S. N. Carvalho, Esq., Jun.
E. C. H. Day, Esq.
H. Fox, Esq.
Lieut.-Col. C. Manby.
Lieut.-Col. E. B. Sladen.
H. B. Whitehead, Esq.
Capt. H. T. Wing.

Fellows Removed (5).

Jonathan Harrison, Esq.
J. Trubshaw Johnson, Esq.
Lewis Thomas Lewis, Esq.
W. Harrison Peacock, Esq.
William Salmon, Esq.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1880.

Professor Gustave Dewalque of Liége.
Professor Adolf Eric Nordenskiöld of Stockholm.
Professor Ferdinand Zirkel of Leipzig.

The following Personages were elected Foreign Correspondents during the year 1880.

Dr. Ferdinand von Hochstetter of Vienna.
Professor Leo Lesquereux of Columbus.
M. Alphonse Renard of Brussels.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Sir P. de M. Grey-Egerton, Bart., and Prof. A. C. Ramsay, retiring from the office of Vice-President.

That the thanks of the Society be given to Dr. H. Hicks, Prof. T. M'Kenny Hughes, Prof. T. Rupert Jones, Prof. J. Prestwich, and Prof. A. C. Ramsay, retiring from the Council.

After the Balloting-glasses had been duly closed, and the lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

R. Etheridge, Esq., F.R.S.

VICE-PRESIDENTS.

J. Evans, D.C.L., LL.D., F.R.S.
J. W. Hulke, Esq., F.R.S.
Prof. J. Morris, M.A.
H. C. Sorby, LL.D., F.R.S.

SECRETARIES.

Prof. T. G. Bonney, M.A., F.R.S.
Prof. J. W. Judd, F.R.S.

FOREIGN SECRETARY.

W. W. Smyth, Esq., M.A., F.R.S.

TREASURER.

J. Gwyn Jeffreys, LL.D., F.R.S.

COUNCIL.

H. Bauerman, Esq.
Rev. J. F. Blake, M.A.
Prof. T. G. Bonney, M.A., F.R.S.
W. Carruthers, Esq., F.R.S.
Prof. P. M. Duncan, M.B., F.R.S.
Sir P. de M. Grey-Egerton, Bart., M.P., F.R.S.
R. Etheridge, Esq., F.R.S.
J. Evans, D.C.L., LL.D., F.R.S.
Lieut.-Colonel H. H. Godwin-Austen, F.R.S.
J. C. Hawkshaw, Esq., M.A.
Rev. Edwin Hill, M.A.
W. H. Hudleston, Esq., M.A.
J. W. Hulke, Esq., F.R.S.
J. Gwyn Jeffreys, LL.D., F.R.S.
Prof. J. W. Judd, F.R.S.
Prof. N. S. Maskelyne, M.P., M.A., F.R.S.
Prof. Morris, M.A.
J. A. Phillips, Esq.
F. W. Rudler, Esq.
Prof. H. G. Seeley, F.R.S.
W. W. Smyth, Esq., M.A., F.R.S.
H. C. Sorby, LL.D., F.R.S.
H. Woodward, LL.D., F.R.S.

LIST OF

THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1880.

Date of Election.

1827. Dr. H. von Dechen, *Bonn.*
1829. Dr. Ami Boué, *Vienna.*
1844. William Burton Rogers, Esq., *Boston, U. S.*
1848. James Hall, Esq., *Albany, State of New York.*
1850. Professor Bernhard Studer, *Berne.*
1851. Professor James D. Dana, *New Haven, Connecticut.*
1853. Count Alexander von Keyserling, *Rayküll, Russia.*
1853. Professor L. G. de Koninck, *Liége.*
1854. M. Joachim Barrande, *Prague.*
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. R. Goeppert, *Breslau.*
1857. Professor H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *Vienna.*
1859. Professor A. Delesse, *Paris.*
1859. Dr. Ferdinand Roemer, *Breslau.*
1860. Dr. H. Milne-Edwards, For. Mem. R.S., *Paris.*
1862. Professor Pierre Merian, *Basle.*
1864. M. Jules Desnoyers, *Paris.*
1866. Dr. Joseph Leidy, *Philadelphia.*
1867. Professor A. Daubrée, *Paris.*
1870. Professor Oswald Heer, *Zurich.*
1871. Dr. S. Nilsson, *Lund.*
1871. Dr. Henri Nyst, *Brussels.* (*Deceased.*)
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Alphonse Favre, *Geneva.*
1874. Professor E. Hébert, *Paris.*
1874. Professor Édouard Desor, *Neuchâtel.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Fridolin Sandberger, *Würzburg.*
1875. Professor Theodor Kjerulf, *Christiania.*
1875. Professor F. August Quenstedt, *Tübingen.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. Dr. F. V. Hayden, *Washington.*
1879. Major-General N. von Kokscharow, *St. Petersburg.*
1879. M. Jules Marcou, *Salins.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
1880. Professor Adolf Eric Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1880.

Date of Election.

1863. Dr. G. F. Jäger, *Stuttgart.*
1863. M. S. Lovén, *Stockholm.*
1863. Count A. G. Marschall, *Vienna.*
1863. Professor G. Meneghini, *Pisa.*
1863. Signor Giuseppe Ponzi, *Rome.*
1863. Signor Quintino Sella, *Rome.*
1863. Dr. F. Senft, *Eisenach.*
1864. M. J. Bosquet, *Maestricht.* (*Deceased.*)
1864. Dr. Charles Martins, *Montpellier.*
1866. Professor J. P. Lesley, *Philadelphia.*
1866. Professor Victor Raulin, *Bordeaux.*
1866. Baron Achille de Zigno, *Padua.*
1870. Professor Joseph Szabó, *Pesth.*
1870. Professor Otto Torell, *Lund.*
1871. M. Henri Coquand, *Marseilles.*
1871. Professor Giovanni Capellini, *Bologna.*
1872. Herr Dionys Stur, *Vienna.*
1872. Professor J. D. Whitney, *Cambridge, U. S.*
1874. Professor Igino Cocchi, *Florence.*
1874. M. Gustave H. Cotteau, *Auxerre.*
1874. Professor W. P. Schimper, *Strasburg.* (*Deceased.*
1874. Professor G. Seguenza, *Messina.*
1874. Dr. J. S. Newberry, *New York.*
1874. Dr. T. C. Winkler, *Haarlem.*
1875. Professor Gustav Tschermak, *Vienna.*
1876. Professor Jules Gosselet, *Lille.*
1876. Professor Ludwig Rütimeyer, *Basle.*
1877. Professor George J. Brush, *New Haven.*
1877. Professor A. L. O. Des Cloizeaux, For. Mem. R.S., *Paris.*
1877. Professor E. Renevier, *Lausanne.*
1877. Count Gaston de Saporta, *Aix-en-Provence.*
1879. Professor Pierre J. van Beneden, For. Mem. R.S., *Louvain.*
1879. M. Édouard Dupont, *Brussels.*
1879. Professor Guglielmo Guiscardi, *Naples.*
1879. Professor Franz Ritter von Kobell, *Munich.*
1879. Professor Gerhard vom Rath, *Bonn.*
1879. Dr. Émile Sauvage, *Paris.*
1880. Dr. Ferdinand von Hochstetter, *Vienna.*
1880. Professor Leo Lesquereux, *Columbus.*
1880. M. Alphonse Renard, *Brussels.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. L. Agassiz.
1837. { Capt. T. P. Cautley. / Dr. H. Falconer.
1838. Professor R. Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. { M. Elie de Beaumont. / M. P. A. Dufrénoy.
1844. The Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. The Rev. Dr. W. Buckland.
1849. Professor Joseph Prestwich.
1850. Mr. William Hopkins.
1851. The Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. / M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. / Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Professor Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Professor Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Mr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Professor Carl F. Naumann.
1869. Dr. H. C. Sorby.
1870. Professor G. P. Deshayes.
1871. Professor A. C. Ramsay.
1872. Professor J. D. Dana.
1873. Sir P. de M. Grey-Egerton.
1874. Professor Oswald Heer.
1875. Professor L. G. de Koninck.
1876. Professor T. H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Professor Bernhard Studer.
1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON "DONATION-FUND."

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Professor G. P. Deshayes.
1838. Professor Richard Owen.
1839. Professor G. C. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Professor Edward Forbes.
1842. Professor John Morris.
1843. Professor John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. / M. Alcide d'Orbigny. }
1849. Mr. William Lonsdale.
1850. Professor John Morris.
1851. M. Joachim Barrande.
1852. Professor John Morris.
1853. Professor L. G. de Koninck.
1854. Mr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Professor G. P. Deshayes.
1857. Mr. S. P. Woodward.
1858. Mr. James Hall.
1859. Mr. Charles Peach.
1860. { Professor T. Rupert Jones. / Mr. W. K. Parker. }
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.
1872. Mr. James Croll.
1873. Professor J. W. Judd.
1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Mr. W. J. Sollas.
1879. Mr. S. Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

ROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Mr. Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Prof. H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Mr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Rev. J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Mr. C. Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Professor A. Geikie. *Medal.*
1881. Mr. F. Rutley.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced."

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Dr. W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Mr. John Evans. *Medal.*
1880. Professor F. Quenstedt.
1881. Professor J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

Dr. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. Charles Barrois.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions for Quarterly Journal ..	3	5	4			
Due for Arrears of Annual Contributions	210	0	0			
Due for Arrears of Admission-fees	44	2	0			
				257	7	4
Estimated Ordinary Income for 1881 :—						
Annual Contributions from Resident Fellows, and Non-residents of 1859 to 1861				1400	0	0
Admission-fees				252	0	0
Compositions				241	10	0
Annual Contributions in advance				12	12	0
Dividends on Consols and Reduced 3 per Cents				238	10	2
Advertisements in Quarterly Journal....................				7	10	0
Sale of Transactions, Library-catalogues, Ormerod's Index, and Hochstetter's New Zealand..	30	0	0			
Sale of Quarterly Journal, including Longman's account	215	0	0			
Sale of Geological Map, including Stanford's account	25	0	0			
				270	0	0
Sale of Stock for Library Catalogue				268	10	0
				£2947	19	6

J. GWYN JEFFREYS, TREAS.

12 *Feb.* 1881.

the Year 1881.

EXPENDITURE ESTIMATED.

	£ s. d.	£ s. d.
House Expenditure:		
Taxes and Insurance	33 10 0	
Gas	25 0 0	
Fuel	40 0 0	
Furniture	20 0 0	
House-repairs and Maintenance	35 0 0	
Annual Cleaning	20 0 0	
Washing and sundry small Expenses	40 0 0	
Tea at Meetings	20 0 0	
		233 10 0
Salaries and Wages:		
Assistant Secretary	350 0 0	
Clerk	140 0 0	
Assistant in Library and Museum	110 0 0	
House Steward	105 0 0	
Housemaid	40 0 0	
Errand Boy	32 10 0	
Charwoman and Occasional Assistance	50 0 0	
Attendants at Meetings	8 10 0	
Accountants	8 8 0	
		844 8 0
Official Expenditure:		
Stationery	25 0 0	
Miscellaneous Printing	24 0 0	
Diagrams at Meetings	5 0 0	
Postages and other expenses	75 0 0	
		129 0 0
Library		150 0 0
Museum		5 0 0
Publications:		
Geological Map	50 0 0	
Quarterly Journal £915 0 0		
,, ,, Commission, Postage, and Addressing... 85 0 0		
	1000 0 0	
List of Fellows	36 0 0	
Abstracts, including Postage	95 0 0	
Library Catalogue	268 10 0	
		1449 10 0
Balance in favour of the Society		136 11 6
		£2947 19 6

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1880.	14	4	1			
Balance in Clerk's hands, 1 January 1880.	1	11	8			
				15	15	9
Compositions				241	10	0
Arrears of Admission-fees	88	4	0			
Admission-fees, 1880	308	14	0			
				396	18	0
Arrears of Annual Contributions				189	11	6
Annual Contributions for 1880, viz.:—						
Resident Fellows	£1329	16	6			
Non-Resident Fellows	26	15	6			
				1356	12	0
Annual Contributions in advance				23	2	0
Journal Subscriptions in advance				0	16	4
Dividends on Consols	207	1	10			
,, Reduced 3 per Cents.	30	7	6			
				237	9	4
Taylor & Francis: Advertisements in Journal, Vol. 35.				7	17	0
Publications:						
Sale of Journal, Vols. 1–35	126	13	8			
,, Vol. 36 *	93	12	4			
Sale of Transactions	0	14	9			
Sale of Library Catalogue	2	5	0			
Sale of Geological Map†	26	0	10			
Sale of Ormerod's Index	2	2	10			
Sale of Hochstetter's New Zealand	0	16	0			
				252	5	5
*Due from Messrs. Longman, in addition to the above, on Journal, Vol. 36, &c.	61	3	1			
†Due from Stanford on account of Geological Map	8	10	1			
	£69	13	2			
				£2721	17	4

We have compared the Books and Accounts presented to us with this statement, and we find them to agree.

(Signed) J. CLARKE HAWKSHAW, F. G. HILTON PRICE, } *Auditors.*

27 *Jan.* 1881.

Year ending 31 *December*, 1880.

EXPENDITURE.

	£	s.	d.	£	s.	d.	£	s.	d.
General Expenditure:									
Taxes				18	5	10			
Fire-insurance				12	0	0			
Furniture				20	15	6			
House-repairs				33	16	8			
Fuel				38	15	0			
Light				23	12	5			
Miscellaneous House-expenses				113	1	7			
Stationery				20	10	4			
Miscellaneous Printing				52	7	6			
Tea at Meetings				18	17	6			
							352	2	4
Salaries and Wages:									
Assistant Secretary (five quarters)				437	10	0			
Clerk				140	0	0			
Library and Museum Assistants				140	8	4			
House Steward				105	0	0			
Housemaid				40	0	0			
Occasional Attendants				8	10	0			
Accountants				7	7	0			
							878	15	4
Library							149	12	4
Miscellaneous Expenses, including postages							71	16	9
Diagrams at Meetings							3	14	0
Investment in £100 Consols							98	10	0
Publications:									
Geological Map				1	14	0			
Journal, Vols. 1–35				9	14	7			
,, Vol. 36	£877	10	5						
,, ,, Commission, Postage, and Addressing	82	15	11						
				960	6	4			
Abstracts				93	3	1			
							1064	18	0
Balance in Bankers' hands, 31 Dec. 1880				96	0	6			
Balance in Clerk's hands, 31 Dec. 1880				6	8	1			
							102	8	7
							£2721	17	4

"Wollaston Donation Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1880	31	16	10	Award to Mr. T. Davies	21	6	10
Dividends on the Fund invested in Reduced 3 per Cents.	31	15	7	Cost of striking Gold Medal awarded to Prof. A. Daubrée	10	10	0
				Balance at Bankers', 31 Dec. 1880	31	15	7
	£63	12	5		£63	12	5

"Murchison Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1880	19	11	8	Award to Mr. R. Etheridge, with Medal	39	3	4
Dividends on the Fund invested in London and North Western Railway 4 per cent. Debenture Stock	39	2	6	Balance at Bankers', 31 Dec. 1880	19	10	10
	£58	14	2		£58	14	2

"Lyell Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1880	51	13	6	Award to Mr. John Evans, with Medal	21	0	0
Dividends on the Fund invested in Metropolitan 3½ per cent. Stock	68	15	0	" Prof. F. Quenstedt	47	18	0
				Balance at Bankers', 31 Dec. 1880	51	10	6
	£120	8	6		£120	8	6

"Barlow-Jameson Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1880	39	6	5	Purchase of a Microscope for the Society's use	33	10	0
Dividends on the Fund, invested in Consols	14	13	10	Balance at Bankers', 31 Dec. 1880	20	10	3
	£54	0	3		£54	0	3

"Bigsby Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1880	6	3	0	Balance at Bankers', 31 Dec. 1880	12	5	9
Lividends on the Fund invested in New 3 per Cents	6	2	9				
	£12	5	9				

Valuation of the Society's Property; 31*st December*, 1880.

Property.	£	s.	d.	£	s.	d.	Debts.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. xxxvi. &c.				61	3	1	Balance in favour of the Society	8452	0	0
Due from Stanford on account of Map				8	10	1				
Due from Subscribers to Journal (considered good)				3	5	4				
Balance in Bankers' hands, 31 Dec. 1880				96	0	6				
Balance in Clerk's hands, 31 Dec. 1880				6	8	1				
Funded Property:—										
Consols, at 98	7150	0	0	7007	0	0				
Reduced 3 per Cents. at 98	1036	5	5	1015	10	11				
Arrears of Admission-fees (considered good)				44	2	0				
Arrears of Annual Contributions (considered good)				210	0	0				
				£8452	0	0		£8452	0	0

[*N.B. The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]

J. GWYN JEFFREYS, *Treas.*

12 *Feb.* 1881.

Award of the Wollaston Medal.

The Reports of the Council and of the Committees having been read, the President, Robert Etheridge, Esq., F.R.S., presented the Wollaston Gold Medal to Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S., and addressed him as follows:—

Professor Duncan,—

It is with no ordinary pleasure that the Council have awarded to you the Wollaston Medal, the highest honour that it is in their power to bestow, in recognition of the valuable services which you have rendered during so many years to the advancement of Geology, and especially of Palæontology; and I may add that it is equally productive of gratification to me that this honour is to be formally conferred upon you by my hands. Since the year 1863 palæontologists have been indebted to you for no fewer than twenty-six memoirs relating to the history, structure, and distribution of the fossil Actinozoa, a group which you have made peculiarly your own by long-continued and most careful researches. Further, you have enriched the publications of the Palæontographical Society with several most important treatises on the British Fossil Corals, supplementary or, rather, perhaps, complementary to the classical Monograph of MM. Milne-Edwards and Haime.

These labours alone, and the value of their results, might have justified the Council in awarding you the Wollaston Medal; but besides your researches upon the Actinozoa, we have to point to several important papers upon the fossil Echinodermata, to others relating to subjects of Physical Geology (also freely touched upon in your more special memoirs), and particularly to your exceedingly important work in connexion with the Geological Survey of India, in describing the fossil corals of that Peninsula, and discussing the questions of both zoological and geological interest which naturally arise out of the study of those organisms. Few, indeed, of our Fellows are in a better position to appreciate your valuable labours than myself; scarcely a day passes that I have not occasion to consult one or more of your contributions; and the more I consult them the more I am convinced of their value. Patiently and unobtrusively, for nearly twenty years, you have followed out the line of research necessary for the fulfilment of your self-imposed task; you have sacrificed the advantages of professional life to devote your energies to the advancement of science; for seven years (from 1864 to 1870) you gave the Society the benefit of your services as one of its Honorary Secretaries, and for two years (1876, 1877) you worthily occupied the Presidential Chair. Such considerations as these would not alone, perhaps, have warranted the award of the Council; but the recollection of such services rendered to the Society is hardly out of place, as supplementing those more generally appreciable merits upon which the award was really founded. On all accounts it is with much pleasure that I hand to you the Wollaston Medal.

Professor Duncan, in reply, said,—

Mr. President,—

The gift which you have presented to me, in the name of the Geological Society, I receive with feelings of great respect and thankfulness. This Medal comes to me bringing a twofold pleasure; for it is a distinction which has been hallowed and ennobled from its reception by a long succession of illustrious men, amongst whom were the founders of our science, our teachers, and many of our best friends; and because, in presenting it to me, you have spoken so sympathetically in appreciation of my scientific work—work which I have been enabled to bring before the world in consequence of the advantages which this Society has placed within my reach. Cheered by this expression of your approbation, I shall labour on in this our common and much-loved science, endeavouring always to merit the esteem of the Fellows of this Society.

Award of the Murchison Medal.

The President then presented the Murchison Medal to Prof. Archibald Geikie, F.R.S., F.G.S., and addressed him as follows:—

Prof. Geikie,—

If any one Fellow of our Society more than another could be selected to receive the Murchison Medal for his valuable contributions to Geology, it would be yourself; since no man living has contributed more to the advancement of that science which it is the special object of our Society to cultivate and diffuse. Your labours in the field connected with your duties as Director of the Geological Survey of Scotland, your learned and valuable contributions to the Journal of our Society, the Transactions of the Royal Society of Edinburgh, the Glasgow Geological Society, and other publications too numerous to mention, eminently qualify you to be the recipient of the Medal founded by your late chief and friend Sir Roderick Murchison. To enumerate your contributions to the literature of the geology of Scotland, or your many important writings connected with our science, would lead me too far—some thirty papers, besides educational works, have resulted from your industry and knowledge. Your able paper on the "Old Red Sandstone of Scotland," published in the Transactions of the Royal Society of Edinburgh, would of itself entitle you to the highest consideration of the Society. Able, indeed, are other contributions, especially those "On the Chronology of the Trap Rocks of Scotland," "On the Date of the last Elevation of Central Scotland" (in vol. xviii. of our Journal), "On the Phenomena of Succession amongst the Silurian Rocks of Scotland" (Trans. Glasgow Geol. Soc. vol. iii.), and "On Earth Sculpture." The Council believed, too, that it would be gratifying to you to receive as a mark of their esteem and sense of your untiring labours, the Medal founded by one with whom in earlier life you were closely associated, and whose endowed Chair of Geology in the University of Edinburgh you have been the first to fill.

Prof. Geikie, in reply, said,—

Mr. President,—

If any thing could add to the gratification with which I receive this honour from the Geological Society, it would be the very kind and flattering terms in which you, Sir, have made the award, and the Fellows have been pleased to receive the announcement. The Geological Society of London has always seemed to me to be truly the Geological Society of the British Empire, electing its Fellows and bestowing its rewards, not in a local, but in a truly catholic and generous spirit. This conviction was renewed and strengthened in my mind on receipt of the unexpected intimation of the bestowal of one of the Society's Medals upon myself, as my contributions to science have but rarely appeared in the Society's publications, and I am so seldom able to be present within the Society's walls. I receive the Medal with peculiar pleasure; first, as a valuable mark of the Society's recognition, and next, as another link of association with the memory of Murchison, which is one of the most precious possessions of my life.

Award of the Lyell Medal.

The President next handed the Lyell Medal to Mr. Warington W. Smyth, F.R.S., F.G.S., for transmission to Dr. J. W. Dawson, F.R.S., F.G.S., of Montreal, and addressed him as follows:—

Mr. Warington Smyth,—

Sir Charles Lyell, in founding the Medal that bears his name, intended that it should serve as a mark of honorary distinction, and as an expression on the part of the governing body of the Society of their opinion that the Medallist has deserved well of science. I need hardly say that the Council, in awarding the Lyell Medal to Principal Dawson, have done so with a sincere appreciation of the high value of his truly great labours in the cause of Palæontology and Geology. When I refer to his published papers, I find that they number nearly 120, and that they give the results of most extensive and valuable researches in various departments of geology, but more especially upon the palæontology of the Devonian and Carboniferous formations of Northern America. No fewer than 30 of these papers have appeared in the pages of our own Quarterly Journal. Considering the nature of these numerous contributions, the Council would have been fully justified in awarding to Dr. Dawson one of its Medals, upon the sole ground of the value of their contents; but these are far from representing the whole of the results of his incessant activity in the pursuit of science. His 'Acadian Geology,' 'Post-pliocene Geology of Canada,' and 'Fossil Plants of the Devonian and Upper Silurian of Canada' are most valuable contributions to our knowledge of North American Geology; whilst in his 'Archaia,' 'The Dawn of Life,' and other more or less popular writings, he has appealed, and worthily, to a wider public. We are indebted to his researches for nearly all our knowledge of the fossil flora of the Devonian and other Precarboniferous rocks of America, and of the structure and flora of the Nova-Scotian coal-field; and, finally, I must refer especially to his original investigation of the history, nature, and affinities of *Eozoon*. These researches are so well known that they have gained for Dr. Dawson a world-wide reputation; and it is as a slight mark of their esteem, and their high appreciation of his labours, that the Council have awarded to him this Medal, which I will request you to forward to him, with some verbal expression of the feeling with which it is offered.

Mr. Warington W. Smyth, in reply said—

That it gave him much pleasure to receive this Medal for Dr. Dawson, who much regretted that he was unable personally to be present, but had addressed a letter to the President expressing his sense of the honour conferred upon him, in the following terms:—

"I regret that distance and the claims of other duties prevent me from appearing in person to express to the Geological Society my sense of the honour conferred upon me by the award of the Lyell Medal.

"This expression of approval on the part of those whose good opinion I value so highly is doubly grateful to one who is so deeply sensible of the imperfection of scientific work done in circumstances of isolation from the greater centres of scientific life, and under the pressure of the severe demands made in a new and growing country on those engaged in educational pursuits.

"It is further especially gratifying to me that this token of your kindly recognition is connected with the illustrious and honoured name of Sir Charles Lyell. Forty years ago the foundation of my geological education was laid by the late Prof. Jameson and other able educators in natural science, his contemporaries, in Edinburgh; but in so far as I have been able to build any thing worthily on this substructure, the credit is due to the study of the 'Principles of Geology,' and to the personal friendship and generous kindness of Sir Charles Lyell more than to any other cause."

Award of the Bigsby Medal.

The President then handed the Bigsby Medal to Prof. Morris, F.G.S., for transmission to Dr. Charles Barrois, and addressed him as follows:—

Prof. Morris,—

The Council of this Society have selected Dr. Charles Barrois to be the recipient of the Bigsby Medal, and have awarded it to him for his numerous papers and contributions to geological science. Dr. Barrois's chief or most important work (written in the year 1876, and published at Lille) is entitled 'Recherches sur le terrain crétacé supérieur de l'Angleterre et de l'Irlande,' a production almost exhaustive in its description of the Cretaceous rocks of England and Ireland, and of the utmost value to English students of geology. Dr. Barrois in this work has been the first to attempt to arrange the English Cretaceous rocks in Palæontological zones, and eminently has he succeeded in defining and correlating the horizons of France and Britain. He is also the author of a 'Mémoire sur le terrain crétacé du Bassin d'Oviédo, Espagne,' with a palæontological description of the Echinodermata by Gustave Cotteau. His great industry and untiring zeal for geological science entitle him to the consideration of the Council; and I therefore beg you to forward to him the Bigsby Medal as our recognition of his services, and, according to the wishes of the founder, we look forward to other and equally valuable contributions.

Prof. Morris, in reply, said:—

Mr. President,

I have much pleasure in receiving the Bigsby Medal for transmission to Dr. C. Barrois in recognition of his labours for the promotion of geological science. I feel assured that while he will fully appreciate the award, it will be also satisfactory to his geological colleagues in the north of France, and especially to that energetic and accomplished geologist, Prof. Gosselet, under whose tuition and encouragement he has been partly stimulated to prosecute those researches which have this day been recognized by the Council of the Geological Society.

Not only, Sir, as you have justly stated, has Dr. Barrois contributed to our knowledge of the physical and palæontological conditions of the Cretaceous rocks of the north of France and of this country, but among other researches he has been occupied with the Palæozoic strata of Brittany and also of Northern Spain, on which latter, he informs me, a memoir will shortly be published. In conlusion I may read the following extract from a letter received from Dr. C. Barrois, who regrets exceedingly that a previous engagement rendered it impossible for him to express personally his grateful sense of the honour done to him by this award. He says:—

"Will you please present my best thanks to the Society for having judged my labours for the advancement of geological science worthy of the Bigsby Medal.

"It is a great and quite unexpected honour for me to have my name on the list of all the good geologists who have received the Medals of the old and illustrious London Geological Society. By the award of the Bigsby Medal I feel myself honoured in the highest degree, as nothing can be more precious to a scientific man than the recognition of his endeavours by the masters and leaders of his own special science. I was already greatly indebted to English geologists as having so often used and profited by their works during my travels in Great Britain. I now incur a new debt to them, as the Bigsby Medal conferred upon me is given, according to the donor's bequest, 'to those not too old for further work.' I am thus mightily stimulated to work for the performance of my duty; I will endeavour to discharge it and to become worthy of so high an encouragement."

Award of the Wollaston Donation Fund.

In handing to Prof. J. W. Judd, F.R.S., Sec. G.S., the balance of the Wollaston Donation Fund for transmission to Dr. Ramsay H. Traquair, F.G.S., the President said:—

Professor Judd,—

In handing to you, to be forwarded to Dr. Traquair, the balance of the proceeds of the Wollaston Donation Fund, I have to request that you will inform him of the feeling of the Council, that it is rarely that they can have the opportunity of awarding this fund to a more able and accomplished naturalist than himself. His long-continued researches upon the Ganoid Fishes of the Carboniferous formation have rendered his name eminent in this department of Palæontology. As an accomplished anatomist and zoologist, we must have every confidence that his treatment of these Vertebrates in the memoir which he is contributing to the publications of the Palæontographical Society will be of the most careful and judicious description, whilst the value of this and his other works is vastly enhanced by the beautiful figures with which he illustrates them. Under these circumstances it affords me much pleasure to place in your hands, for transmission to Dr. Traquair, the balance of the Wollaston Fund, which I hope he will receive as some recognition on the part of the Society of the value of his researches, and, at the same time, as a small aid to him in further prosecuting them.

Prof. Judd, in reply, read the following communication, received from Dr. Traquair—

"Mr. President,—

"Permit me cordially to thank the Geological Society for the honour which it has conferred upon me by adding my name to the list of those who, in former years, have received this award.

"If the subject of Fossil Ichthyology is not only fascinating, but essential to the student interested in the great problems of Vertebrate Morphology and Descent, it cannot fail also to be of importance to the geologist, who, calling to his assistance every available branch of natural knowledge, seeks to arrive at a scientific conception of the past history of the earth and its living inhabitants. It is, therefore, very gratifying to me to receive from the Geological Society of London this very unexpected token of sympathy and recognition, considering that the amount of work which I have been able to achieve in this field is as yet comparatively small. It will, however, stimulate me to further exertions; for the field is itself a large one, and in spite of the magnificent labours of Agassiz and the accumulated researches of many other writers, still affords room for plenty of work."

Award of the Murchison Geological Fund.

The President next presented the balance of the proceeds of the Murchison Donation Fund to Frank Rutley, Esq., F.G.S., and addressed him in the following words:—

Mr. Rutley,—

For many years you have devoted your time and attention to the microscopical structure of rocks and rock-forming minerals, a branch of scientific research of the highest importance to the petrologist and geologist; and now that our attention is being so much drawn to the structure of the metamorphic and igneous rocks, with a view to a better nomenclature and a revision of old and obsolete views, the Council of our Society believed that in your hands good work would still be carried on; they, therefore, have awarded to you the balance of the Murchison Fund, which I have much pleasure in handing to you in recognition of your past researches, the results of which you have from time to time communicated to the Journal of the Society. Few are more aware than myself of the interest you take in this branch of study, and it affords me much gratification to be the medium of conveying to you the appreciation of the Council and the accompanying fund.

Mr. Rutley, in reply, said that he felt deeply the honour thus conferred upon him, which was additionally gratifying to him personally, as it was associated with the name of a former distinguished Director-General of the Geological Survey. With regard to his own special work, to which the President had alluded in such kind terms of praise, he remarked that in all such work the investigator is particularly liable to fall into error, and that all special microscopical researches upon petrological subjects need to be constantly checked by observations in the field. It was a further gratification to him to receive the award of the Council, for which he wished to express his gratitude, from the hands of an old teacher, to whose instructions he was indebted for the habits of minute and careful investigation inculcated in his lectures.

Award of the Lyell Geological Fund.

In presenting to G. R. Vine, Esq., one moiety of the balance of the proceeds of the Lyell Donation Fund, the President addressed him as follows:—

Mr. Vine,—

A moiety of the balance of the proceeds of the Lyell Geological Fund has been awarded to you by the Council of the Geological Society. In making this award the Council were actuated in part by the wish to express their sense of the value of your researches upon the fossil Bryozoa of the Palæozoic rocks, as evinced especially by your published writings on the Diastoporidæ, an exceedingly difficult group, and in part by their desire to assist you in the further prosecution of your investigations. I have much pleasure in handing to you this small testimony of the appreciation of the Council.

Mr. Vine, in reply, said:—

Mr. President,—

I receive through you this token of recognition, on the part of the Council, of my humble labours, with mingled feelings of pleasure and pride. I cannot, at present, understand the reason why I should be selected as one of the recipients of the Lyell Fund. It cannot be for what I have done for science; for, as yet, my name is young; it must be that, having looked upon my labours with favour, the Council desires to stimulate me to further exertions. If such be the motive, I shall do my utmost to fulfil the higher promise which my hitherto crude efforts have awakened. When, some years ago, I began to study the Carboniferous Polyzoa, I wrote to Prof. Duncan, F.R.S., asking for certain information respecting these Polyzoa; he wrote me back word saying that he did not know much about the species himself, and he did not think that there were many men in England who did; but he counselled me to go to work and find out for myself, and then he and others would be glad to know. Accepting this advice, I set to work, with results which you and the Council so kindly acknowledge to-day by this award.

From your hands, Mr. President, I feel also proud in accepting the award. Many years ago, when poor and unknown, I sought information on this and other things from the cases of the Museum of Practical Geology. On that occasion you helped me by word and deed to name my private series of fossils—a kindness on your part that I never have forgotten or shall forget.

To the Fellows of the Geological Society I also tender my thanks for the manner (judging by the discussions which have followed the reading of my papers) in which they have received my criticisms on a most difficult group of fossils. I may differ from many of you in the future, but I shall hope to do so in such a manner as to show that I do not forget that we are fellow-students and at the same time gentlemen.

The PRESIDENT then handed to Prof. H. G. SEELEY, F.R.S., F.G.S., for transmission to Dr. ANTON FRITSCH, of Prague, the second moiety of the Lyell Donation Fund, and said:—

Professor SEELEY,—

The Council has awarded a portion of the Lyell Geological Fund to Dr. Anton Fritsch, Professor of Zoology in the University of Prague, in recognition of his valuable contributions to palæontology. Dr. Fritsch is an accomplished zoologist, who has enriched his studies of many groups of fossils, invertebrate and vertebrate, with admirable knowledge of existing life. During the last thirty years Dr. Fritsch has published about one hundred and twenty memoirs, many of which relate to palæontology and geology. Besides scattered papers on *Eozoon*, *Callianassa*, and other subjects connected with the fossil fauna of Bohemia, Dr. Fritsch has also published some standard works monographing the fossils of his native land. These comprise memoirs on the Cretaceous Cephalopods (1872), the Cretaceous Reptiles and Fish (1878), and his great work on the Fauna of the Permian Rocks (still in progress), of which two volumes, devoted to Amphibia, have been issued. These volumes are excellent examples of descriptive work, illustrated worthily, and this award is especially intended to mark the sympathy of the Council with Dr. Fritsch in his endeavours to adequately make known the Permian fauna, and in the hope that the fund may assist him in completing a work which has already taken high rank among palæontological monographs.

Prof. SEELEY, in reply, said:—

Mr. PRESIDENT,—

Dr. Fritsch will, I believe, appreciate the honour of the award which you have made, no less than the words in which you have expressed the esteem in which his work is held in this country. I have seen the materials upon which his studies of the Amphibia are founded, and doubt whether any more important work has been done in palæontology during the past year, or whether it could have been accomplished at all by any one less skilled in the methods of zoology than Dr. Fritsch. His enthusiasm for research has given to his works a wealth of illustration that will help materially in the advance of knowledge, while by electrotyping the specimens he has rendered them easily available for study by all anatomists. I shall have great pleasure, Mr. President, in informing Dr Fritsch of the kindly way in which your award has been received by the Society.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

ROBERT ETHERIDGE, Esq., F.R.S.

In accordance with the usual practice, I must commence my Address with brief Obituary Notices of some of the more prominent Fellows and Members of the Society whose loss we have had to deplore since the last Anniversary Meeting.

SEARLES VALENTINE WOOD, born Feb. 14, 1798, died Oct. 26, 1880. He became a Fellow of the Geological Society in 1839.

Mr. Wood was born on St. Valentine's day; hence his name. He went to sea as a midshipman in the 'Thames' (one of the East-India Company's mercantile fleet) in 1811, and continued in that service until the year 1826, when, being disappointed in obtaining the command of a ship that had been promised him, he retired from a maritime life and devoted himself to palæontological studies. Settling in his native place in Suffolk, he gave the larger part of his attention to the Crag: but he also collected extensively from the Hampshire Tertiaries; and for the purpose of working out the relations of these to the beds of the Paris basin, he formed an extensive collection of the French Eocene Mollusca.

From these materials, and from correspondence with Deshayes and other French savans, he was prepared to have taken up the description of the English Eocene Mollusca long before he actually did so, circumstances having determined his undertaking the description of the Mollusca from the Upper Tertiaries first. He also formed a considerable collection of recent Mollusca for comparison in working out the relations of the Mollusca from Tertiary formations. Having left Suffolk from ill health, and settled in London, he was in 1837 introduced to Sir Charles (then Mr.) Lyell, and was associated with him in the endeavour in which Lyell was then mainly engaged, to work out a better knowledge of the Tertiary formations, which up to a period not long before that time had been regarded as of small account in comparison with the "Secondary" group. In this task Lyell relied principally on S. V. Wood and the late G. B. Sowerby for the determination of the identity of the Molluscan remains from various countries with those found fossil in England, and with the Molluscan fauna living in existing seas, so far as these were then known. Mr. Wood also, for a few months about this time, acted as Curator of the Museum of the Geological Society.

Urged to the task by Lyell, he commenced (with the cooperation of the present Mr. G. B. Sowerby as engraver and intended publisher) the description of the 'Crag Mollusca;' and considerable progress had been made with the manuscript and plates of the first or "Univalve" part of this work, when the Palæontographical Society was formed, in 1847; this part formed the first volume of the magnificent series of scientific publications which have been issued by that Society. The rest of the 'Crag Mollusca' followed in subsequent years; and upon the completion of this work, and in recognition of his labours generally in connexion with the Tertiary Mollusca, the Council of the Geological Society awarded to Mr. Wood in the year 1860 the Wollaston Medal. A large supplement to this work, embodying the discoveries which had subsequently accumulated, was prepared by Mr. Wood; and this, accompanied by an introduction describing geologically the formations from which the remains embraced by the work had been obtained, from the pen of his son and of Mr. F. W. Harmer, was issued by the Palæontographical Society in 1871 and 1873. A second supplement followed this in 1879; and Mr. Wood was actively engaged, up to the day of his seizure with fatal illness, on another small addition. On the completion of the description of the Molluscan remains from the Crag, Mr. Wood presented the unrivalled collection of them, which he had been forming during thirty years, to the nation, in order that, by being preserved intact in the British Museum, the types of all the forms which had been described and figured by him in his work (save two or three which belonged to other persons) might be available for examination and comparison by naturalists engaged in similar labours.

He also presented to the nation the valuable collection of vertebrate remains (including among them the unique jaws of *Alligator hantoniensis* and *Microchœrus erinaceus*) which he had, in 1843-5, extracted from the Eocene Freshwater beds of Hordle Cliff, from which beds up to the time when he commenced forming this collection no such remains had been known. These he partially figured and described in the London Geological Journal; but the stoppage of that publication brought this part of his labours to an unexpected termination. In 1858, having the advantage of an unrestricted manipulation of the more extensive collection of Eocene Mollusca which had been formed by his friend F. E. Edwards, he commenced the description of the Eocene Bivalvia, Mr. Edwards taking upon himself (and having commenced before this) the Cephalopoda and Gasteropoda. Several parts of this work were issued by the Palæontographical Society. Failure of health put a somewhat premature period to Mr. Edwards's share in this work; but Mr. Wood continued his labours for some years longer, relinquishing them only when, shortly before Mr. Edwards's death, his collection was acquired by the British Museum. During the time in which it remained in Mr. Edwards's possession he was accustomed to place in Mr. Wood's care, for study at his leisure, all specimens he possessed which in any way illustrated the subject in hand; but this the transfer of the collection to the British Museum rendered impracticable; and as it was Mr. Wood's feeling that, in addition to that opportunity for careful study, all forms as to which any doubt existed ought to be carried abroad and compared with those in the museums of France and Belgium, if justice was to be done to the subject, and as at his advanced age he was unable to accomplish this, he on the issue of the part in the volume of the Palæontographical Society for 1870 relinquished the further prosecution of the 'Eocene Bivalvia,' although he subsequently added a small contribution (both to Mr. Edwards's and his own portion) on special groups of Eocene Mollusca, which he was able to do from resources afforded by his own collection and the collections of some friends.

He maintained his activity both of mind and body up to the day of his seizure with fatal illness, which took place on the 21st and terminated with his death on the 26th of October last. He was buried in the churchyard of Melton, near Woodbridge, in view of the Crag of which the study had occupied so much of his life.

John Jeremiah Bigsby, M.D., F.R.S., one of the oldest of our Fellows, and a man endeared to all who knew him by many amiable qualities, died at his residence in Gloucester Place on the 10th February in the present year. He was the son of Dr. John Bigsby, and was born at Nottingham on the 14th August, 1792; so that at his death he was in his 89th year.

Deciding to follow his father's profession, he took his degree of Doctor of Medicine at Edinburgh; and soon afterwards he must have entered the military service, as, from a chance note in one of his books, it appears that he was at the Cape in 1817. In 1818 or 1819 he went to Canada as the Medical Officer to a large detachment of a German Rifle Regiment in the British Service; and in Canada he remained for several years performing a variety of commissions intrusted to him by the Government. Thus in the summer following his arrival in the Colony he was sent to the Hawkesbury Settlement, where a severe epidemic of typhus fever had broken out among the miserable Irish immigrants; and in the next year his marked taste for Geological studies led to his being commissioned to travel through Upper Canada and make a general report upon its Geology. In 1822 he was appointed British Secretary and Medical Officer to the Boundary Commission, which had already been in existence for three or four years. In the journeyings to and fro necessitated by these employments Dr. Bigsby had many opportunities of making himself acquainted with the geological phenomena of regions then very little known; and it is chiefly to these that his published papers relate. In 1823 he was elected a Fellow of this Society.

He appears to have returned to England about the year 1827, and then proceeded to practice his profession at Newark in Nottinghamshire, remaining there until 1846, when he came to London, where he afterwards resided until the end of his life.

Dr. Bigsby was elected a Fellow of the Royal Society in 1869, and received the Murchison Medal from this Society in 1874.

His published papers are about twenty-seven in number; the earliest, entitled, "Remarks on the Environs of Carthage Bridge, near the mouth of the Genesee river," appeared in Silliman's American Journal in the year 1820. It was followed by several other papers on geological subjects in the same periodical. In 1823, the year of his election, he forwarded a paper to this Society "On the Geography and Geology of Lake Huron," which was published in 1824, in the first volume of our 'Transactions.' Until his return to England his contributions to scientific literature made their appearance chiefly in American publications; and for some years after his return he seems to have done but little, his medical practice probably occupying his time very fully. After his removal to London, however, several papers from his pen were communicated to the Society; and among them may be noticed especially his paper "On the Palæozoic Basin of the State of New York," which appeared in the Quarterly Journal for 1858, and was followed by "An Inquiry into the Sedimentary and other Natural Relations of the Palæozoic Fossils of the State of New York," published in 1859; his note "On the Erratics of Canada," printed in the Journal for 1851; and his last communication to our 'Proceedings,' "On Missing Sedimentary Formations," published in 1864. Other memoirs of his appeared in various periodicals, such as the 'Philosophical Magazine' and the 'Annals and Magazine of Natural History,' the last of them bearing date 1867.

The narrative of his Canadian travels appeared in 1850, in two octavo volumes, under the fanciful title of 'The Shoe and Canoe.' Although evidently written by the light of knowledge subsequently obtained, it furnishes an interesting account of the condition of Canada some sixty years ago, and is rendered amusing by the display of that *naïve* geniality mingled with shrewdness which characterized the author to the end of his life. It contains many scattered popular notes on geological and other natural-history subjects.

During the last twenty years of his life Dr. Bigsby was engaged in a work of great labour and research, the first outcome of which was the 'Thesaurus Siluricus,' published, with the aid of a grant from the funds of the Royal Society, in 1868. It is a list of described Silurian fossils, classified both zoologically and in accordance with their distribution in time; and although, no doubt, errors and defects may be detected in it, it will remain for a long time a most useful aid to the student of Silurian Palæontology, and a monument of the untiring industry of its author. The same things may be said, perhaps in still stronger terms, of a second publication of the same nature, the 'Thesaurus Devonico-Carboniferus,' which appeared in 1878, a wonderful example of industry and research in a man eighty-five years old; and not content with these labours, Dr. Bigsby, to the close of his life, was hard at work upon a Permian Thesaurus, the MS. of which is left in an advanced state. The last books borrowed for the compilation of this work were only returned to the Society's Library when Dr. Bigsby took finally to his bed.

The memory of our late lamented Fellow will be worthily kept alive by the Medal which he founded in the year 1877. The greater part of Dr. Bigsby's fortune having accrued to him by marriage, he gave himself only a life-interest in it, and decided that the whole amount at his decease should go to the relations of the ladies whom he had married and survived. Hence, from delicacy of feeling, he decided that instead of bequeathing a sum of money to the Society for the purpose of founding a Medal, he would provide the necessary funds out of his income during his life; and accordingly, in the above year, he gave the Society a sum of money the interest of which was to be devoted to providing a Medal to be given biennially, preferentially to those who had studied American geology, with the further stipulation that the receiver should be not more than forty-five years old, and "thus probably not too old for further work, and not too young to have done much." At first the Medal was to have been of bronze and accompanied by a sum of money, the balance of the proceeds of the fund; but subsequently the founder increased the amount of his donation sufficiently to enable the Council to give a Gold Medal. In 1877 the Medal was awarded to Prof. O. C. Marsh, and in 1879 to Prof. E. D. Cope; this year it goes to Dr. C. Barrois.

Rev. James Clifton Ward. The announcement of the death of Mr. Ward must have been to most of his many friends wholly unexpected, both on account of the early age at which he passed away, and the very brief illness which preceded his decease.

After a weakly boyhood he entered the Royal School of Mines as a student in 1861, entirely through my suggestion, and gained the Edward Forbes Medal and prize of books in 1864. In the following year he joined the Geological Survey, and was sent down to Yorkshire. He worked there on the Millstone-grit and Lower Coal-measures in the neighbourhood of Sheffield, Penistone, Huddersfield, Halifax, and Leeds. Though Ward was never of robust appearance, he obviously improved in health after leaving the School of Mines; so well did the laborious but healthy work of the Survey agree with him.

In 1869 he was transferred to Keswick; and the change from a colliery district to a locality not only devoid of coal-pits, but one in which wild Nature puts forth all her charms, was in the highest degree pleasing to him. At Keswick his activity became twofold. His Survey work and its results are now represented by his Geological Survey memoir on the Geology of the Northern part of the English Lake District (published in 1876), and by numerous maps and sections. He also contributed to the Geological Society, and to various periodicals, many papers bearing on the structure of the Lake Country. Of these may be mentioned, in the first place, two on its glaciation, entitled, "The Origin of some of the Lake Basins of Cumberland" (Quart. Journ. Geol. Soc. 1874), and "The Glaciation of the Southern Part of the Lake District" &c. (Quart. Journ. Geol. Soc. 1875). In both papers the origin of the lakes is discussed; and (as regards the English Lake country) the original investigations of the author tend to confirm the views so long held by Prof. A. C. Ramsay. These papers are illustrated with sheets of sections of the highest interest and value; and to make the work more complete, the results of a series of soundings carefully taken on most of the lakes by this indefatigable worker are also given.

In the years 1875 and 1876, and more recently, microscopical examination of the rocks of the Lake District occupied much of his time. Of papers on this subject I may here note one "On the Granitic, Granitoid, and Associated Metamorphic Rocks of the Lake District," the first part of which appeared in the Quart. Journ. Geol. Soc. for 1875, and the second in the volume of the same periodical for 1876. Another paper is entitled, "Notes on the Comparative Microscopic Rock-Structure of some Ancient and Modern Volcanic Rocks," and appeared in the Quart. Journ. Geol. Soc. for 1875. Among his latest contributions to geological literature may be mentioned "Notes on the Geology of the Isle of Man," which appeared in the Geological Magazine for January, 1880. The following is by no means an exhaustive list of his productions:—

1. In 1868, "Internal Fluidity of the Earth." Geol. Mag. v. pp. 581, 582.

2. In 1869, "Suggestions as to Geological Time." Geol. Mag. vi. pp. 8–13.

3. In 1869, "On Beds of supposed Rothliegende Age near Knaresborough." Quart. Journ. Geol. Soc. xxv. pp. 291–297.

4. In 1870, "On the Denudation of the Lake District." Geol. Mag. vii. pp. 14–17.

5. In 1871, "The Development of Land." Geol. Mag. viii. pp. 11–15.

6. In 1872, "On Rock-staining." Geol. Mag. ix. pp. 389–391.

7. In 1873, "On the Scenery of the English Lake District, geologically considered." Brighton, Proc. Nat. Hist. Soc. xx. pp. 39–44.

8. In 1873, "On Rock-fissuring." Geol. Mag. x. pp. 245–248.

9. In 1873, "The Glaciation of the Northern Part of the Lake District." Quart. Journ. Geol. Soc. xxix. pp. 422–441.

10. In 1870, "Coral Reefs and the Glacial Period." Quart. Journ. Sci. iii. pp. 170–178.

But the most characteristic side of his untiring energy, and perhaps its most important one, was the zeal with which he worked for the diffusion of scientific knowledge while in Cumberland. Before leaving Yorkshire he had written a small elementary book on Physics; and one of the firstfruits of his educational activity at Keswick was a similar work on Geology, composed of nine lectures delivered in the first place before a school audience, and secondly before the Keswick Literary Society. Being simple, clear, and free from unnecessary technicalities, his lectures soon became popular, and the lecturer himself acquired influence.

As the originator and main support of the Cumberland Association for the Advancement of Literature and Science, and of most of the local societies connected with it, he accomplished a work which it may be hoped will not now be suffered to languish, but will remain a lasting monument of his beneficent activity. A glance at the outer cover of the 'Transactions of the Cumberland Association' (Part IV. was published at the beginning of this year) shows the date at which each of the associated societies was founded, and discloses the fact that only one of them (at Whitehaven) existed before Ward's appearance in the county. The dates of the others vary from Keswick 1869 to Silloth, the latest, 1879.

He married at the beginning of the year 1877, and very shortly after left the Lake country to do field-work in the lone barren district of Bewcastle, on the Lower Carboniferous rocks, wintering, however, in Keswick as before. But on finishing the Bewcastle work he made preparations for taking Holy Orders, and was licensed to the curacy of St. John's, Keswick, in December 1878. He was as successful in his new duties as he had been as a geological surveyor, and was appointed, at the beginning of last year, to the vicarage of Rydal. But he was scarcely established in his new home when a brief illness, which only at the last seemed dangerous, caused his departure, at the age of thirty-seven years, leaving behind him a widow and two children.

His genial disposition, and the absence in him of the least approach to the temper of the dogmatist, caused him to number among his friends men of every shade of speculative opinion. It was this amiability, in addition to his ability as a lecturer and the single-mindedness of his desire for the spread of knowledge, which made him so successful in connexion with the Cumberland Association, when the simple fact of his not being a Cumbrian by birth would have been fatal to any merely active and zealous man.

David Thomas Ansted was born in London on the 5th February, 1814, and, after education at a private school, entered the University of Cambridge as a member of Jesus College. He was 32nd Wrangler in the year 1836, and proceeded to the degree of M.A. in due course in 1839. About four years afterwards he was elected to a fellowship on the Ley Foundation of Jesus College, which he retained for about eight years. In 1840 he was elected Professor of Geology at King's College, London, which office he resigned in 1853. For some time, from 1845, he held the Lecturership on Geology at Addiscombe, and was also Professor of Geology at the College of Civil Engineers, Putney. From 1844 to 1847 he was Vice-Secretary of the Geological Society and Editor of the Quarterly Journal. He became a Fellow in 1838. He was elected to the Fellowship of the Royal Society in 1844. In 1868 he was appointed Examiner in Physical Geography to the Science and Art Department.

By degrees his attention became diverted from the theoretic to the practical aspect of his favourite study; and for the last thirty years of his life he acted professionally as a consulting geologist and mining-engineer. For some time before his death he was in failing health; and he expired on the 13th May, 1880, at his residence, Melton, near Woodbridge, Suffolk.

Professor Ansted, however, when systematic teaching ceased to be a part of his regular duties, did not abandon his interest in geology as an educational subject, but not unfrequently lectured and took part in examinations on this and allied sciences. His pen also was rarely for long idle. He contributed three papers to the Journal of the Geological Society, two of them containing descriptions of remarkable mineral veins, published in 1856 and 1857; his third paper was upon the geology of Malaga and the southern part of Andalusia (vol. xv. 1859). Besides these contributions to the 'Quarterly Journal of the Geological Society,' he published memoirs in:—the 'Transactions of the Cambridge Philosophical Society' (vol. vii. 1842), "On a Portion of the Tertiary Formations of Switzerland;" in the 'Annals and Magazine of Natural History,' "On the Zoological Condition of Chalk Flints and the probable Cause of the Deposit of Flinty Strata alternating with the Upper Beds of the Cretaceous Formation" (vol. xii. 1844), and other like publications. He was whole or part author of a considerable number of volumes, the majority of which were of a somewhat popular character; and more than one obtained a considerable share of success. He wrote lucidly and pleasantly, whether upon matters directly scientific or upon the incidents of travel. Among these works may be mentioned the following:—'Geological Gossip,' first published in 1860; 'A Short Trip to Hungary and Transylvania,' in 1862; 'The Ionian Islands,' in the year 1863; and 'The Great Stone Book of Nature,' published in the same year. He also published a work on Geology, in two volumes, in 1844, and more than one smaller book on this subject, Physiography, or Geography. He was joint author (with Dr. R. G. Latham) of a work on the Channel Isles, and wrote, in 1866, upon the Physical Geography and Geology of Leicester, in the 'History of Leicestershire,' entering largely into the lithology and chemistry of the Charnwood rocks, as well as devoting much space to their pure and speculative geology. In the Great Exhibitions of 1851 and 1862 he contributed much to the 'Reports.' His latest, and one of his most important works, was on Water and Water Supply, published in 1878. Though for several years, owing to pressure of business and the advance of age, he had ceased to take an active part in the proceedings of many of the scientific societies of which he was formerly an energetic member, he did not lose that cordiality of manner and kindliness of disposition which have left a pleasant impression on the memory of his friends.

In William Hallowes Miller, Professor of Mineralogy in the University of Cambridge, our Society has lost a member who, though never a contributor to our Journal, was among the most eminent mineralogists in Europe, and the author of valuable works and papers on that science. He was born April 6th, 1801, at Velindre, near Llandovery, in Caermarthenshire, at which place his father, Captain Miller, had a few years previously fixed his residence. The associations of the family were military, his father having served through a part of the American war, by which he had been a heavy loser, and other relatives having held commissions and obtained distinction in the British army. W. H. Miller was educated at private schools, and afterwards entered as a student at St. John's College, Cambridge, graduating in the year 1826, when he was fifth among the Wranglers in the Mathematical Tripos. In 1829 he was elected to a Fellowship at his College, and subsequently proceeded to the degrees, first of M.A., and afterwards (in compliance with the statutes by which it was then governed) of M.D. For some time he filled the office of a College Tutor; and his first literary work was a 'Treatise on Hydrostatics,' published in 1831, and followed a few years subsequently by one on Hydrodynamics. At this time the chair of Mineralogy at Cambridge was occupied by Dr. Whewell; and under his guidance Mr. Miller devoted himself to the study of Crystallography, with so much success that, on the resignation of Dr. Whewell, he was elected to the Professorship, the duties of which became the chief work of his long and arduous life. In 1830 he was elected a Fellow of our Society, and in 1838 a Fellow of the Royal Society. Six years afterwards he vacated, by marriage, his Fellowship at St. John's College; but in 1874 he was again elected under the statute (granted in 1860) empowering that Society to elect as Fellows persons eminent for science or learning, though otherwise technically disqualified. Not long after this his health began to fail; and in the autumn of 1876 a course of lectures, which he had announced, was interrupted by a slight stroke of paralysis. This proved the beginning of the end. He was never able to meet his class again. Very slowly, but surely, his vital powers declined, a torpor stealing alike over body and mind, until at last he fell asleep on the 20th May, 1880.

Professor Miller's name is inseparably connected with two important branches of scientific work. The first of these belongs, as might be expected, to mineralogy. "Crystallography," as has been said by Professor Maskelyne, "was Miller's science." Other workers, indeed, had preceded him in laying the foundation and contributing important materials; but Professor Miller, "taking the important memoir by Professor Whewell 'On the Geometrical Treatment of Crystal Forms' (published in the 'Transactions of the Cambridge Philosophical Society'), and Naumann's treatise of 1823 ('Beiträge zur Krystallonomie') as his starting-point, proceeded to develop a system of crystallography, which was not published till 1838, but which was the most important work of his life." The especial feature of this book and of his labours in this science "consisted in working out into a beautiful system the indicial method of notation and calculation in crystallography, and obtaining expressions adapted for logarithmic calculations by processes of great elegance and simplicity. Miller's system, then, gave expressions for working all the problems that a crystal can present; and it gave them in a form that appealed at once to the sense of symmetry and appropriateness of the mathematician." He thus, as it has been well said, "placed the keystone into the arch of the science of crystallography;" and the "future development of that science, there can be little doubt, will follow on the lines laid down by Miller."

Professor Miller's shorter communications on mineralogy and physics are numerous and valuable, and; in addition to them and to his original treatise, he published, in 1863, a tract on crystallography. In 1852 a work appeared entitled a new edition of the 'Elementary Introduction to Mineralogy, by the late William Phillips,' by H. J. Brooke and W. H. Miller. It is, however, no disparagement to either the original author or his fellow editor to say that Professor Miller made this volume almost his own.

But Professor Miller's reputation does not rest only upon his work as a mineralogist, great though that was. His name is no less inseparably connected with the difficult and delicate experiments and investigations connected with the restoration of the standards of measurement and weight, and with the subsequent labours of the International Metric Commission.

After the fire which, in 1834, consumed the Houses of Parliament, it was found that the standards of measurement and weight were hopelessly ruined. Professor Miller was not a member of the Commission appointed to consider the questions connected with their restoration, but lent the Commissioners much friendly assistance. Then, in 1843, a Committee was appointed to superintend the construction of the new Parliamentary standards of length and weight, of which Professor Miller was a member; and to him was confided the construction of the new standards of weight. In the 'Philosophical Transactions' for 1856 he describes at length "the operations for restoring the value of the old standard of weight, for constructing the new standard of a different value, for constructing various derived standards, and for establishing the relative value of the kilogramme," a paper which (to quote the words of the Astronomer Royal, indorsed by a former President of the Royal Society, Sir Edward Sabine) "will long be cited as a model of accuracy."

He was subsequently a member of a new Royal Commission for "examining into and reporting on the state of the secondary standards, and for considering every question which could affect the primary, secondary, and local standards."

In the year 1870 he was appointed a member of the "Commission Internationale du Mètre."

He was appointed Foreign Secretary of the Royal Society in 1856, a post for which he was eminently fitted by his accurate and extensive knowledge of French, German, and Italian, his methodical habits, and unvarying courtesy, as well as by his extensive scientific knowledge.

He received in 1865 the degree of LL.D. from the University of Dublin, and in 1876 that of D.C.L. from Oxford. In 1870 he was awarded a Royal Medal by the Royal Society. He was a

Knight of the Order of St. Maurice and St. Lazaro of Italy, and of the Order of Leopold of Belgium. He was also an honorary member of the Royal Society of Edinburgh and of numerous foreign societies.

Three characteristics especially distinguished Professor Miller. One was the remarkable extent, depth, and accuracy of his knowledge, not only on those questions which he had made peculiarly his own, but also on all branches of physical science, only equalled by the liberality with which he opened his rich stores of learning to others, and especially to younger students. Another was the simplicity of his disposition. This, combined with a remarkable inventiveness of mind, was shown even in his laboratory, where the most homely odds and ends were utilized in the construction of instruments capable of performing delicate measurements. The third characteristic was the remarkable combination which he exhibited of independence of thought and freedom of opinion with gentleness of temper and speech, with forbearance, courtesy, and respect for the opinion of others.

Blessed with much domestic happiness, and beloved by all who knew him, he lived a tranquil and blameless life, devoted to earnest work and the faithful performance of every duty, and passed away lamented by a large circle of friends and admirers in this and other countries.

Henry Ludlam. We have to record the loss of Mr. Henry Ludlam, F.G.S., who died on the 23rd of June, 1880, at the age of 58.

Early a student of the natural sciences, Mineralogy became his favourite subject, in the cultivation of which he was greatly assisted by the study of chemistry, which occupied many of the leisure evening hours which the care of an important business allowed him. Aided by an unusually critical judgment, he gathered together a large and valuable collection of minerals, in which some of the specimens were conspicuous for their perfection of crystalline form. To these he subsequently added the well-known and important collection which belonged to the late Mr. Charles Hamden Turner, of Rooksnest, Surrey, and also that made by the late Mr. William Nevill, F.G.S., of Godalming. The whole forms certainly the most complete and probably the finest collection of minerals ever made by a private collector.

But Mr. Ludlam was not a mere collector. He had long had in view the desirability of preparing a complete descriptive and crystallographic catalogue of that which it had been his good fortune to accumulate. This great work, to which he looked forward as to a labour of love, was actually commenced by him shortly before the illness which ended in his premature death.

Although Mr. Ludlam never contributed a paper to the 'Journal of the Geological Society,' he nevertheless took much interest in its proceedings. His great liberality in the support of every thing bearing upon the kindred sciences to geology, and his munificence as a collector possessing great knowledge of his subject, entitles him to notice in the obituary list of our Fellows. He left by will the whole of his superb collection of minerals to the museum in Jermyn Street for the use of all students. It is now, therefore, the property of the nation. Science, through the early death of Mr. Ludlam, has lost an earnest student, while his personal friends have to lament the loss of a warm-hearted and true English gentleman.

Robert Clutterbuck, F.G.S., was the eldest son of Robert Clutterbuck, the historian of Hertfordshire. Mr. Clutterbuck was educated at Harrow, being head boy of that School in 1817. He entered as a commoner at Exeter College, Oxford, where, previous to taking his degree, he gained University honours. He then entered as a law student under the tuition of the late Sir William Hayter. Mr. Clutterbuck spent some time on the continent, gaining an unusual proficiency in the Italian and French languages. During his residence at Watford he acted as a magistrate, and was instrumental in raising funds for the restoration of the abbey or cathedral of St. Alban's. As an author Mr. Clutterbuck was well known through his works on the monsoons &c., and on the rotatory action of storms; he also published accounts of his journeys over the great desert from Aleppo to Bassora, and the passage by Suez through Egypt to determine the possibility of an overland communication with India. Mr. Clutterbuck never contributed to the 'Journal of the Geological Society;' but he wrote a paper on the Coprolite beds at Hinsworth, which was published in the 'Transactions of the Watford Natural History Society,' vol. i. 1878. He died September 15th, 1879.

Dr. Edward Meryon, F.R.C.P., F.G.S., &c., was many years Fellow of the Geological Society, and some time member of the Council, taking much interest in the working of the Society. He never contributed any paper to the Journal. He, however, was the author of several important works bearing upon his profession, among which may be mentioned especially 'The History of Medicine,' 'The Physical and Intellectual Constitution of Man,' 'The Functions of the Sympathetic System,' and 'Practical and Pathological Researches on the various Forms of Paralysis. Dr. Meryon was an accomplished and practical physician of great professional experience. He was an accomplished scholar and true-hearted gentleman. Dr. Meryon died November 8, 1880.

In Elijah Walton, who died at his house near Bromsgrove on August 25, 1880, in his forty-eighth year, the Society has lost an artist who has been equalled by few, perhaps surpassed by none, in his power of rendering faithfully the forms of mountains and the structure of rocks. His studies of clouds and of the camel prove the versatility of his genius and the fidelity of his execution; but it is in his pictures of the mountains of Sinai, Norway, and the Alps that his excellence in rock-drawing of every kind is conspicuous. Overwork and anxiety first clouded and then terminated a life which once seemed full of brilliant promise.

Dr. Wilhelm Philipp Schimper, Professor of Geology in the Faculty of Sciences, Director of the Museum of Natural History, and Professor in the University of Strasburg, a Corresponding Member of the French Academy of Sciences and of the Academies of Munich, Lisbon, and Philadelphia, elected a Foreign Correspondent of the Geological Society in 1874, died of disease of the heart on the 20th March, 1880.

Dr. Schimper was descended from a family living in the Palatinate, the connexion of which with Alsace was at all times close, and especially so during the first French empire. His father at this time became the Protestant pastor of Dossenheim, near Saverne, in Alsace; and here Schimper was born in 1808. He was educated at first by his father, and from an early period showed a great taste for natural history, which continued to manifest itself after he had temporarily left the paternal roof, at the age of 14, to pursue his studies at the College of Bouxwiller. Here he remained until 1826, when he went to Strasburg, and there, in 1833, took his degree as Bachelor of Divinity. He subsequently acted for a time as curate to his father, who was then pastor at Offwiller.

The young Schimper, however, seems to have devoted his attention more to Natural History, especially Botany, than to theological studies; and he had acquired such a knowledge of the Mosses, that as early as 1834 the eminent botanist Bruch proposed to him that they should produce a joint monograph on the European forms of that class of plants. Schimper acceded to the proposal, and, with the view of devoting himself exclusively to natural-history studies, resigned his ecclesiastical functions, not without opposition on his father's part, and in 1835 accepted the position of preparator in the Museum of Natural History at Strasburg. With that establishment he remained connected until the day of his death, having been reinstated in his various offices by the German authorities after their annexation of Alsace.

The work on European Mosses above mentioned was produced by Schimper alone. It is entitled 'Bryologia Europæa, seu genera Muscorum Europæorum, Monographia illustrata,' and is a monument of the author's industry and botanical attainments, extending to six 4to volumes, with an atlas of 641 plates. Its publication was commenced in 1836, but was not completed until nearly twenty years afterwards (namely, in 1855). The author's bryological publications did not cease then, however: he afterwards produced several supplements to his great work, besides other memoirs on Mosses, and a 'Synopsis Muscorum Europæorum,' of which the second edition appeared in 1874.

In procuring materials for the above work, Schimper travelled a good deal in various parts of Europe; and on his journeys he was indefatigable in collecting specimens of all kinds for the enrichment of the museum under his charge. He acquired a very wide knowledge of general natural history, and paid much attention to geological phenomena, which, in conjunction with the direction of his special botanical studies, early led him to the investigation of fossil plants, upon which he was destined to become one of the chief authorities of our day. He associated himself with Köchlin-Schlumberger in the preparation of a great memoir upon the Terrain de Transition des Vosges, published at Strasburg in 1862; to this Schimper contributed the monograph of the fossil plants.

In 1849 he married a Swiss lady who had been long an ardent student of botany, and who afterwards assisted him in his studies, and especially in the accumulation of the vast stores of materials upon which he founded his greatest work, the 'Traité de Paléontologie Végétale,' published in three large 8vo volumes, with a 4to atlas of plates, of which the first volume appeared in 1869. This important treatise upon the fossil flora will long be a standard work of reference. Subsequently Schimper commenced the botanical section of Prof. Zittel's admirable 'Handbuch der Paläontologie,' which, however, he did not live to complete.

Joseph Augustin Hubert Bosquet, of Maestricht, Doctor of Sciences, Pharmacien, Member of the Royal Academy of Sciences of Amsterdam, was elected a Foreign Correspondent of the Geological Society in 1864. In 1868 the Council awarded the balance of the proceeds of the Wollaston Donation Fund to Dr. Hubert Bosquet as a reward for his valuable researches on the Tertiary and Cretaceous strata of Holland and Belgium. Dr. Bosquet worked out with great industry and ability the fauna of the Maestricht beds, a division of the Upper Chalk not present in England. His researches amongst the Tongrian beds greatly extended our knowledge of these Tertiary deposits, both as regards their palæontology and physical conditions. Bosquet's labours were undertaken and carried on amidst business duties, and with zeal and ability rarely excelled. He was the author of twelve or fourteen contributions both to geological and palæontological science. His chief papers are:—"Description des Entomostracés fossiles de la craie de Maestricht" (Mém. Soc. Sci. Liége, vol. vi. 1847); and "Description des Entomostracés fossiles des terrains tertiaires de la France et de la Belgique" (Mém. Couronn. Bruxelles, xxiv. 1850–51). His papers entitled "Les Crustacés fossiles du terrain Crétacé du Limbourg" (Nederland. Geol. Kaart Verhand. ii. 1854) and "Recherches Paléontologiques sur les terrains tertiaires du Limbourg Néerlandais" (Amsterdam, Verhand. vii. 1859), are of much importance. Dr. Bosquet died on the 28th of June, 1880, aged 66 years and 10 months.

Pierre Henri Nyst, Conservator at the Museum of Natural History at Brussels, was elected a Foreign Correspondent of this Society in 1863, and in 1871 was elected a Foreign Member. He was a Member of the Royal Academy of Sciences of Belgium, and was also a Chevalier of the order of Leopold.

In 1874 the Council awarded him the balance of the proceeds of the Wollaston Donation Fund for his admirable, extensive, and original researches upon the Crag Mollusca of Belgium. His chief work is the 'Description des Coquilles et des Polypiers fossiles des terrains tertiaires de la Belgique' (4to, Brussels, 1843). Up to the year 1873, Nyst had written about thirty-six papers, mostly upon recent and fossil conchology. His connexion with the national museum at Brussels, and obliging manner, rendered him at all times accessible to students or those desiring information upon Tertiary palæontology. Nyst died on April 6th, 1880, aged 67 years.

On the Analysis and Distribution of the British Palæozoic Fossils.

The history of so progressive and practical a science as Geology, and its kindred study Palæontology, especially during the past decade, not only in Britain, but in Europe, America, and our Colonies, now needs some revision and analysis, arising from the amount of research, and the progress that has been made in these and collateral sciences during this period.

The history of the Lower Palæozoic rocks of the British Islands is almost the history of Geology; for it extends over forty years. The same may be said of Scandinavia and Bohemia. And parallel to these researches in Europe may be recorded the great progress made in the western hemisphere; for the history of the Lower Palæozoic or oldest rocks of N. America and Canada is but that of Britain and Northern Europe almost repeated; homotaxially they are the same.

The study through many years of the distribution of life through the stratified rocks of the British Islands enables me to lay before the Society some results arrived at by long and patient research. I have, however, only taken advantage of my position on the Geological Survey, which has afforded me facilities otherwise almost impossible of access, and enabled me to carry on practically, both in the field and the study, those branches of our science which bear so intimately upon the progress of Physical Geology and Geography, besides elucidating some of the laws that have governed the distribution of life through time and space.

De la Beche, Lyell, Edward Forbes, Hamilton, Phillips, Huxley, Ramsay, Prestwich, and Duncan, in their learned addresses delivered from this chair, have one and all dealt with questions bearing especially upon stratigraphical geology as based upon the range and distribution of organic remains, phenomena which since the time of William Smith have been studiously kept in mind, teaching us the succession of life and the relation in time of one formation to another—each successive sedimentary group containing undoubted records of its life and deposition, thus rendering clear and definite the changes in, and the advance of life through time.

No more difficult problem exists or remains to be solved than the first appearance or commencement of life on the globe. Is the Laurentian of North America, with its one known solitary form of life, the oldest sedimentary rock existing? is *Eozoon canadense* the oldest form of life? Research up to the present time has not revealed to us one of higher antiquity; neither has it even a truly associated form. No true Annelide, Plant, or Protozoon accompanies this still mysterious progenitor of Palæozoic life.

The Eozoic or Laurentian gneiss of Britain or Europe, has not yet yielded a semblance of any thing approaching Protozoic affinities, although in the Hebrides, Norway, Sweden, Bohemia, and Bavaria the Laurentian rocks have been recognized.

That the Laurentian rocks are not the oldest is manifest; others of infinitely greater age yielded sediment to the Laurentian sea, and pabulum for the sustenance and material for the shelly structure of its supposed only inhabitant; but whether *Eozoon* had precursors or not, time will probably tell.

Dr. Dawson, however, suggests that vegetable life preceded *Eozoon*, and may thus have accumulated previous stores of organic matter. If any older forms of animal life did exist, they cannot have belonged to much simpler types; "naked Protozoa would have left no sign of their existence, except probably minute traces of carbonaceous matter." Dr. Dawson in the year 1865 discussed the question of associated organic structures, and what share, if any, they may have had in the accumulation of the Laurentian Limestone. Microscopic examination exhibited evidence of calcareous and carbonaceous fragments of organic origin. The contents of the organic limestone, as shown by Dr. Dawson, were "Remains of *Eozoon*, other calcareous bodies probably organic, objects imbedded in the serpentine, carbonaceous matters, perforations or worm-burrows." Dr. Dawson strongly and fairly argues for associated life.

The presence of graphite in large deposits occurring both in beds and veins in the Laurentian rocks, clearly determines that its origin and deposition were contemporaneous with the mass or containing rock; the graphite, again, is associated with calcite, quartz, and orthoclase. It is not improbable that the "vein graphite" was introduced as a liquid hydrocarbon. Dr. Sterry Hunt believes it possible that it may have been produced in a state of aqueous solution*. In the lower Laurentians the quantity is enormous. Dr. Hunt also believes that the origin of the graphite was due to the deoxidation of carbonic acid by living plants. That the graphitic

* Hunt, Report of the Geological Survey of Canada, 1866.

matter of the Laurentian rocks was laid down or accumulated in beds like coal is improbable, no evidence whatever tending to show that there existed terrestrial vegetation. On the other hand, the hydrocarbon may have been due to diffused bituminous matter closely resembling " our bituminous shales and bituminous and oil-bearing limestones." Research hitherto has failed to find traces of any organism save the *Eozoon*; no cryptogam has yet occurred; and we cannot imagine that, if of vegetable origin, the organic matter could have been so completely disintegrated and bituminized prior to being changed into graphite. Dr. S. Hunt believes he has determined the presence of terrestrial vegetation in the great beds of Laurentian iron-ore which show subaerial decay, thus implying the "reducing and solvent action of substances produced in the decay of plants." Dr. Dawson long ago (1875) believed that he had found, in the compact graphitic limestones of Clarendon, traces of fibrous structure due to segregation which may be the remains of plants, " and in some specimens vermicular lines " which he believed to be "*Eozoon* penetrated by matter once bituminous, but now in the state of graphite." At the utmost we can only speculate upon the presence or condition of vegetation during the Archæan, or Pre-Cambrian, Laurentian, or Eozoic time.

Dana employs the term Archæan in time, to express in full meaning that era in the physical development of the Earth which was "incompatible with the existence of life," when life was not, so far as we know. Little, however, is known of that vast group of rocks we call Pre-Cambrian, adopting this term as used in this country, on the Continent, and in America, for rocks affording us no history or recognizable records.

Dana again assumes and endeavours to show that four eras preceded the Laurentian period:—

A first or molten era subsequent to that of the presumed original nebulous state.

A second era, one of solidification and consolidation through cooling, when the Earth became solid at the centre; later on, atmospheric vapours became condensed and probably universal; water covered all. The cooling and contracting of the sphere resulted in oceanic depressions in special areas, and our continents were shadowed forth and contoured, but as yet no life can be chronicled.

The third era may have given us surface reliefs; stratified deposits were formed.

The fourth era probably saw the beginning of life, which occurred when the oceanic waters may have stood at 200° F. With this fourth era we may associate the Eozoonal serpentines.

In the British Islands we have yet to find that type of Laurentian rock which yields either of the great limestones of Canada,—the so-called Fundamental Gneiss of Scotland, Malvern, and Ireland having no affinities with the Eozoonal and graphitic group of the North-American continent, and being doubtless of vastly younger date.

To summarize the results of the labours and views of those who have carefully investigated and thought out any great physical question is at all times difficult; and perhaps there are few subjects on which men have theorized and differed more than on the history of the globe. For time and life are two subjects that at once arrest the attention of all earnest students. Our knowledge of the commencement of either is as indefinite now as in the days of the earliest investigators. With the succession of sedimentary rock-masses in the outer framework of the globe we are perhaps partly familiar, certainly so for given and known areas; there are, however, extensive regions yet unknown and unexplored, and remaining to be correlated with the known; and yearly in the Transactions of our Society, through the researches of our Foreign Members and others, are we reminded how insecure and uncertain is our base, how doubtful our succession, when attempted to be universally applied. Yearly some new light is thrown upon the obscure history of the earliest rocks with which we believe ourselves acquainted. Both the early metamorphic and the lowest Palæozoic rocks, even in our own small area, are still waiting for final position and classification; the same may be said of much of Europe, America, Canada, India, and Australia.

Palæozoic time in Europe and Britain may have commenced with the deposition of the so-called earliest Cambrian rocks; but where geographically, we know not—probably far to the west of Ireland and the British Islands, under what is now the deep Atlantic. The north-western coast of Scotland, and Ireland, much of the north-west of England, and North and South Wales all point to a region where we may believe that the earliest known sedimentary rocks of Western Europe, and their life contents had their commencement or origin. Little can be said here of Archæan time and its rocks as developed on the American continent; possibly we may recognize and correlate the Archæan system of Dana with our gneissose schists and so-called Laurentian rocks of the north-west coast of Scotland and the Hebrides.

It would be mere speculation here to attempt to define any strict contemporaneity. We know from the labours of Dana, and the researches of Sir William Logan in the field, and of Billings in the study, that two periods or eras of Archæan time are fully represented in North America and Canada:—1*st, the older or Laurentian*; 2*nd, the Huronian*, this latter in all probability represented by our lowest Cambrian, or those beds underlying the Menevian of St. David's, and also constituting the rocks of Harlech, Llanberris, Bangor, and the Longmynds. We have hitherto discovered no life-remains in the Archæan rocks of the British Islands, our so-called Laurentians having none of the prevalent limestones, Eozoonal or otherwise, of the New-York and Canadian rocks. To trace out the conditions of the northern hemisphere during Lower-Cambrian times, both zoologically and physically, has been and is still one of the most difficult and important problems of modern geological research*. We have long known that the European area was of great extent,

* *Vide* Hicks, Geol. Mag. dec. 2, vol. iii. p. 876, "On the probable Conditions under which the Palæozoic Rocks were deposited over the Northern Hemisphere.'

even before the Cambrian rocks were accumulated: remnants of this early land or continent are still visible and traceable in Spain, France, Scandinavia, Ireland, Scotland, England, and Wales. Gneiss, granitoid rocks, and occasional limestones formed the mass of this Pre-Cambrian land, now exhibited to us in a greatly metamorphosed state, stratigraphically unconformable to the overlying Cambrian, and with a discordant strike north of latitude 30°. These rocks are visible on both sides of the Atlantic as far as the Arctic regions, representing portions of two continents, Europe and America, now separated by the North Atlantic.

Pre-Cambrian Rocks.

It may be received as an axiom that all the known older sedimentary rocks were deposited more or less in a similar manner, or under similar conditions, to those of modern times. Allowing this to be the case, it is most probable that those sedimentary deposits which are the lowest, or have the earliest position, have undergone most change; and it must be admitted that the crystalline, semicrystalline, and metamorphosed state in which they now appear has been subsequently induced through various agencies (heat, pressure, and chemical change) exerted through countless ages. Research seems to prove that most of the rocks now recognized as Pre-Cambrian were originally sedimentary strata, which have undergone, since their deposition, alteration or metamorphism. Few men have paid more attention to the physical history, distribution, succession, and character of this most ancient group of rocks than Dr. Hicks, ably followed by Professor Bonney, Professor Hughes, Mr. Tawney, Dr. Sorby, Professor Hull, and Mr. Hudleston; each of these observers has contributed largely to the elucidation of the history of the Cambrian rocks in his own particular way. Three if not four groups or systems have been determined by Hicks, having definite bearings or discordant strikes one to the other through certain portions of the British Islands. They occur in ascending order, and in the order of time, as follows:—

1. Lewisian. Hebrides and North-west Highlands.
2. Dimetian. St. David's, Caernarvon, and Anglesey.
3. Arvonian. Pembrokeshire, Caernarvonshire, Anglesey, Shropshire, and the Harlech Mountains.
4. Pebidian. South Wales, Shropshire, Charnwood Forest, Anglesey, and Ireland.

Lewisian.—Murchison gave the name Lewisian to the crystalline rocks largely entering into the structure of the Hebrides and North-western Highlands; probably these constitute the oldest group of rocks known or recognized in the British Islands. Red felspar, hornblende, and quartz are the prevailing ingredients in these massive gneisses; occasionally, as at Cape Wrath and on the coast to the south, almost pure hornblende rock occurs. The strike of the Lewisian group is usually east and west, or ranging between that and north-west and south-east.

The Malvern chain may also represent the Lewisian; and also the highlands of North Ireland as developed in Donegal.

Dimetian*.—This group is extensively developed in many parts of South and North Wales; it occurs in Shropshire, and, according to Dr. Hicks, is known in the Worcester Beacon of the Malvern chain; it is also said by Hicks to occur at Ben Fyn, Loch Maree, and near Gaerloch in Ross-shire, and in other areas in the N.W. Highlands.

Unlike the Lewisian type, the Dimetian contains impure chloritic limestones and serpentinous bands (not of organic origin so far as we know). The chief minerals are flesh-coloured and white felspar, and chloritic and hornblendic bands; and the rocks are highly quartzose. Fragments of the older Lewisian gneiss are occasionally found imbedded in the gneiss, thus determining the unconformability of the Dimetian group, through derivation and denudation. Viridite occurs more or less throughout, giving a tinge to the rock. At St. David's the ridge formed by these rocks, according to Dr. Hicks, averages from 2000 to 3000 feet in thickness. "Cambrian conglomerates rest immediately upon the Dimetian rocks; and the highest members of the Harlech group strike up against the Dimetian ridge;" and both sides are flanked throughout by the uncomformable Pebidian group. At St. David's the rocks chiefly composing the Dimetian series are compact crystalline quartz, chloritic schists, and indurated shales; the quartz in places occurs almost perfectly crystalline. Massive beds of calcareous shale and dolomitic limestone occur. "As much as 20 per cent. of carbonates have been determined on analysis by Mr. Hudleston, and in addition 0·5 per cent. of phosphoric acid; hence it is more than probable that the lime was deposited by organic aid" (Hicks). The Pebidian rocks are strongly contrasted by their bedded and shaly character. Dr. Hicks has not discovered any traces of organic life in the inferior limestones, of which five beds occur.

Dr. Hicks estimates the thickness of the St. David's Dimetian at 15,000 feet. Several intrusive dykes traverse the series; and their injection took place before metamorphism had commenced. They are fine-grained altered dolerites, columnar in structure, with the columns at right angles to the plane of the dykes.

Arvonian.—In 1878 Dr. Hicks discovered in Pembrokeshire new areas of Pre-Cambrian rocks of a totally different character from the Dimetian and Pebidian which he had previously described. The rocks of this Arvonian group are marked on the Geological Survey map as intrusive felstones; they occur in three or four isolated masses of considerable extent. Their strike is from north to south, and discordant to those of the newer rocks and the underlying Dimetian.

The wild mountain-region of Plymstone is mainly composed of the Arvonian group. Dr. Hicks finds Lower Cambrian and Lingula-flag rocks resting unconformably upon the "Arvonian" along their

* "Dimetia," the ancient name for a kingdom which included this part of Wales. *Vide* Hicks, "On the Pre-Cambrian (Dimetian and Pebidian) Rocks of St. David's," Quart. Journ. Geol. Soc. vol. xxxiii. p. 229 (1877).

N.W. edge. The texture of this new group is hard and flinty, some portions having an imperfect conchoidal fracture. The chief character or peculiarity consists in the manner in which the quartz is separated or segregated into nests, giving the rock a pseudoporphyritic appearance.

The Arvonians, both generally and microscopically, closely resemble the Swedish "Hälleflintas;" nevertheless associated with them are true quartz-felsites, probably old lava-flows (rhyolitic). The evidence as to the position which the Arvonian occupies in the Pre-Cambrian group is conclusive, as determined by the way in which the Cambrian rocks are faulted down against it. It is certainly Pre-Pebidian, as fragments of the Hälleflinta occur in the overlying Pebidian conglomerates; its rocks occupy a large proportion of the Dimetian axis of St. David's; and, according to the researches of Hicks, that part coloured as syenite and felstone in the Geological map to the N.E. of St. David's must be assigned to the "Arvonian" group, only the lower portion being Dimetian.

Like the Dimetian these rocks are greatly altered, consisting of highly metamorphosed indurated porcellanitic shales. The beds resting upon the Dimetian axis are hard compact conglomerates, composed of quartz and altered shale derived from the Dimetian.

Pebidian*.—The Pebidian rocks are unconformable to the Dimetian, extending along both sides of the Dimetian ridge. They strike from S.W. to N.E., nearly parallel to the ridge, or in accordance with the overlying Cambrian Rocks; they are irregular in thickness and greatly metamorphosed, composed of porcellanitic shales; "the narrow dark lines" of stratification and closely approximating and intersecting joints distinguish the Pebidians from the Dimetian, against which they rest. The "lower beds are hard compact conglomerates, composed of masses of quartz and altered shales," derived from the underlying rocks and closely connected together. These all immediately lie on the Dimetian axis. They are to be seen at Nun's Well, south of St. David's, on both sides of the Caerbuddy valley to the east of the city, and north and south of the cathedral in the valley. This Pebidian group supports the true Cambrian rocks at many places in the neighbourhood. Little more than 3000 feet are exposed; and the strike is nearly identical with that of the overlying Cambrian. The large area coloured as intrusive greenstone upon the Geological Survey map, and extending parallel to Ramsey Sound, is composed of the Pebidians. A considerable portion of the S.W. part of Ramsey Island consists of the compact porcellanites which characterize this series. The Harlech conglomerates rest unconformably upon or along the N.E. edge of the Pebidians†. Basic lavas and breccias predominate over the Rhyolites.

It is stated by Professor Ramsay, in the 'Geology of North Wales'

* So named from "Pebidiauc," the name of the division or hundred where these rocks are exposed near St. David's.

† See Dr. Hicks, Quart. Journ. Geol. Soc. vol. xxxiii. pp. 229–239, for map and sections &c.

(Mem. Geol. Surv. vol. iii. p. 8), that the oldest rocks in Wales and Shropshire appear at the surface in six districts—elevation, denudation, and relative changes having caused to be exposed as six inland islands as many masses, chiefly mountainous, and composed of the oldest sedimentary strata, in Britain, whose true history has yet to be written. In Ireland we may recognize three or four such areas also.

These and others, of the history of whose masses we are still ignorant, constitute the basis and foundation (mostly unfossiliferous) of all succeeding sedimentary strata. They have been of late and still are being subjected to critical examination, both chemically and microscopically. Large areas hitherto believed to be of igneous origin, and long ago mapped as such during the progress of the Geological Survey, are now found under rigorous examination to be sedimentary rocks which have undergone complete metamorphosis since deposition. Such determinations are all-important when we come to consider the earliest appearance of life and its distribution within the British area; for recent investigation has resulted in the removal of certain rocks, hitherto believed to be igneous, to the sedimentary or stratified series. This has been the case, as we have seen, with several important masses in North and South Wales, now designated Pre-Cambrian, assuming them to be a group of rocks of higher antiquity than those in which undoubted traces of life have hitherto been found in Britain.

To the influence of microscopic investigation and research is due the right determination and history of these and other doubtful rocks. Dr. Hicks has described some areas in the Lleyn peninsula along the N.W. shore which he believes to be representative of his Dimetian, Arvonian, and Pebidian groups; and Professor Bonney doubts not, from microscopical examination, the presence here of a considerable Pre-Cambrian series, with at least two very distinct groups of rocks.

Dr. Hicks during the past summer determined the presence of an older series of rocks than the Cambrian of the Harlech or Merioneth anticlinal near the centre of the Harlech Dome. These rocks evidently underlie the Harlech sandstones, and constitute part of a pre-existing formation. The Cambrian conglomerates at the base of the Harlech grits contain fragments of rock identical with this older formation.

No discovery of late has equalled this in importance; it has proved the existence in North Wales of a group or system hitherto unknown, although expected or anticipated. This enables us to compare the thickness of the Cambrian rocks of North Wales with that of those of the same age at St. David's in South Wales, and at the same time to realize and compare the physical conditions of the two. This may enable us to measure the thickness of the Harlech Cambrians, and probably to arrive at the strike of the subjacent rocks. The broken and denuded anticlinal has exposed these Pre-Cambrian rocks, north and south; they are marked in the maps of the Survey as intrusive felstones, but appear to be a highly metamorphic series of schists, alternating with bands of purplish slate, and are believed by Dr. Hicks to be of Pebidian age: the strike is from N.E. to S.W.

Between Caen Cochion and Pen-maen east of Traws-fynnyld road, the Cambrian conglomerates are seen resting unconformably upon the older series; and masses of the Pre-Cambrian occur plentifully in the conglomerate. It is to be hoped that Dr. Hicks will continue his researches over this wild and difficult region; it is highly important to know the precise nature of the axis and underlying rocks of the anticlinal. The researches of Professor Ramsay and the Survey detail all that we really know of the great mass of the Harlech Dome or Merioneth anticlinal *. Caernarvonshire, Anglesey, Shropshire, the Malvern Hills, and Scotland have received critical examination from Dr. Hicks; but his results are too full of detail to be entered upon here.

The physical structure and life-history of the classical promontory of St. David's has of late years, at the hands of Salter and Hicks, received an amount of research and attention of which scarcely any other district can boast.

The rocks composing the ancient headland of Menapiæ are, perhaps, the oldest known rocks containing organic remains in the British Islands, if not in the world; nevertheless the characters presented by the contained organisms are such that we cannot imagine that we have here traces of the earliest manifestations of life upon the earth.

In treating of the various successive formations embraced in the recognized Palæozoic divisions of the British sedimentary rocks, I shall omit altogether any definite classification into great systems. For while we may define one period as characterized by the presence of a certain fauna, which in the next succeeding so-called epoch, is replaced by a different one, there will always be found in some part of their geographical distribution a region where, in some form or condition, the two faunas commingle, and where the old one gradually disappears as the new one comes in or makes its appearance. To assign, therefore, any definite or precise boundary-lines or limitations to our stratified rocks and their contents, when the record of past life is of necessity so incomplete and obscure, is, to say the least, at present premature, if not unphilosophical, however convenient it may to a certain extent be; but the progress of so boundless and progressive a science as Geology with its associated subjects, demands that we should lay down no hard or definite lines, no brackets or definitely constructed tables.

Each year witnesses the breaking-down of arbitrary divisional lines in classification, in Zoology and Palæontology as well as in Geology. Any attempt, therefore, to establish geological divisions or horizons upon either stratigraphical or palæontological breaks must be temporary and local only; probably there exists no break in life, any more than in time or in sedimentation; for some-

* *Vide* Ramsay, Mem. Geol. Survey of Great Britain, vol. iii. Geol. of North Wales, pp. 17–19.

where there will be found continuous and conformable succession both physically and palæontologically. We have no visible chronological scale in Geology but such as is afforded by the relative magnitude of zoological changes; in other words, the geological duration and importance of any system is in strict proportion to the comparative magnitude and distinctness of its collective fauna.

It would be out of place here to enter upon the question which has been long at issue as to the claims of two, if not three, schools of thought and research in relation to the divisions or classification of the Lower Palæozoic rocks.

"To Professor Sedgwick must be conceded the credit of determining and assigning the limits and sequence of the larger subdivisions; for single-handed he laid down with masterly precision the succession and true stratigraphical arrangement of the Lower Palæozoic rocks of Wales, from the Bangor beds to the summit of the Bala group."

"To Sir R. Murchison must also be awarded the high credit of having been the first to distinctively assign to many of these rocks their sequence, distinctive fossils, and palæontological value"*. Conflicting views led to the formation of a third school of research, in which Sir Charles Lyell, Mr. Salter, and Dr. Hicks exercised great influence. These last two observers assigned the term Silurian to all the strata ranging from the top of the Ludlow to the base of the Arenig, and restricted the term Cambrian to all between the base of the Lower Arenig and the lowest known beds of the Harlech and Llanberris group. The Tremadoc group, by its fossils, however, has little in common with the underlying Lingula-flags and Menevians, only sixteen of the Lingula-flag and other forms, out of one hundred and eighty-two that range below the Tremadoc passing up to the latter horizon. The great and almost total break at the top of the Tremadoc lends strong evidence in favour of the division being recognized here.

The recognition of a tripartite grouping of the faunas and strata, between the base of the Old Red Sandstone and the Harlech series, cannot be disputed; each is characteristic, and possesses a broadly-marked aspect or facies—the Primordial Cambrian, or first fauna, the "Ordovician" system, or second fauna, and the Silurian system, or third fauna, according to their succession in time. Sedgwick named his system after the entire principality in which his rocks were typically developed, his title of Cambrian being comprehensive enough to embrace the whole of the Palæozoic rocks. Murchison selected the term Silurian, associating the rocks of his system with the tribe of the Silures.

Mr. C. Lapworth, in his able paper upon the tripartite division of the Lower Palæozoic rocks, has suggested, and with good reason, the name "Ordovician" for all that group of strata in the Great Bala district called Upper Cambrian of Sedgwick or Lower Silurian of Murchison—from the ancient tribe of the Ordovices, who occupied the country now called Montgomeryshire, Merionethshire, Caernarvonshire, Denbighshire, and Flintshire. So long, he remarks, as the

* Geol. Mag. decade 2, vol. vi. pp. 1–15, 1879.

present system of nomenclature exists nothing can disturb the application of the title Cambrian to the rocks of the primordial series, and of Silurian to the strata of the third fauna, or that series of strata intervening between the Old Red Sandstone and the Lower Llandovery. With the intermediate series from the Llandovery to the Lower Arenig "we have had incessant differences respecting nomenclature, proper limits of the groups, and sequence of fossils; they are still designated as Upper Bala, Caradoc, Middle Cambrian, and Lower Silurian. This central system of the Lower Palæozoic may therefore well receive a name equally euphonious and significant of the area where its strata are typically developed" *.

No division of the British sedimentary rocks has given rise to so much controversy as the so-called Cambrian strata. At the present moment they have no fixed or definitely-assigned horizon, either base or summit, beginning or end; their time-history, necessarily their space-development also, rests upon no agreed or recognized determination. Two, if not three, schools of research in these lowest groups of rocks differ even among themselves as to the uppermost limit that should be assigned to the term Cambrian, or where in the field the line of demarcation should be drawn between it and the Silurian, or at the base between it and the Pre-Cambrian or metamorphic series. It is no part of my duty to enter into details relative to the history of the controversy which has so long occupied the minds and attention of the respective advocates of the schools of Sedgwick and Murchison.

The past ten years have witnessed great changes both in the nomenclature and classification of the Cambrian rocks. The name Cambrian, given by Sedgwick in 1838 to the whole group of strata below the May-Hill Sandstone, has of late years again given rise to much controversy. This critical research has been equally important in its bearing upon the investigation of European and American geology and the establishment of a corresponding nomenclature for the succession and history of these oldest known fossiliferous rocks on the globe. Whether we can rightly refer the Dimetian, Arvonian, and Pebidian groups of Britain to the Laurentian and Huronian of Canada is yet a question; that they occur below the recognized Cambrian, there can be no doubt, both from discordancy of strike, petrological differences, and supposed total absence of organic remains. Probably the great groups of rocks comprised under the above names (Laurentian and Huronian), the Archæan of Dana, may be the equivalents in time of our St.-David's and North-Wales Pre-Cambrian; and his Primordial or Cambrian system (embracing the two series Acadian and Potsdam) may represent the lower portion of our fossiliferous Cambrian rocks, or those so well defined and developed at St. David's, viz. the red shales and flaggy beds with *Lingulella ferruginea* and *L. primæva*, the red, purple, and grey grits, the *Plutonia*-beds, the red, grey, and purple flaggy sandstones, and the succeeding grey flaggy series, all five of which are fossiliferous. Not only so, but these Pembrokeshire Cam-

* *Loc. cit.* p. 14.

brian rocks seem to have no equivalents in North Wales, unless they represent in time the Llanberris, Harlech, and Bangor sandstones, grits, and flags, which, however, have as yet yielded no trace of organic remains. Again, very few species are common to these grey, red, and purple sandstones and the succeeding well-developed Menevian group, which has yielded nearly fifty species*; yet in the Harlech, Barmouth, and Dolgelly areas the Menevians immediately succeed, are conformable to the underlying barren unfossiliferous grits, and exhibit the first traces in North Wales of a definite and definable fauna. In other words, the representatives of the Harlech and Llanberris beds in the St.-David's promontory contain a well-marked fauna, highly characterized by the Crustacea (7 genera and 14 species) and by the still more important fact that no species occurring in the Longmynd and Harlech rocks of St. David's are known in North Wales. It is only in the succeeding Menevian (Lowest Lingula-flags) that there is a well-marked community. Of the 12 Pembrokeshire species (9 of which are Trilobita, viz. *Agnostus cambrensis*, *Conocoryphe bufo*, *C. Lyellii*, *C. solvensis*, *Microdiscus sculptus*, *Paradoxides aurora*, *P. Hicksii*, *P. Harknessii*, and *Plutonia Sedgwickii*) not one is known out of the area; whereas of the 28 Menevian species known in the St.-David's area, 12 are common to it and North Wales and 5 are confined to North Wales, viz. *Agnostus reticulatus*, Ang., *Anopolenus impar*, Hicks, *Conocoryphe coronata*, Barr., *C. Homfrayi*, Salt., and *Erinnys venulosa*, Salt.; 7 are common to both areas, and 16 peculiar to the Menevian promontory. These will be referred to under the Menevian group.

This non-occurrence of fossil remains other than Annelide-burrows (*Chondrites* and *Cruziana*) in the Cambrian of the Geological Survey has much significance when they are compared with groups of rocks equivalent in time, and not far removed geographically, metamorphism not having affected their original condition so as to have obliterated all traces of life. The sequence in both areas (North and South Wales) is the same, as proved or determined by the position of the Menevian beds, which in South Wales have a fossiliferous base in grey, red, and purple sandstones, these, again, resting upon a Pre-Cambrian foundation of highly metamorphosed rocks, divisible into three systems or formations, which Dr. Hicks has denominated Dimetian, Arvonian, and Pebidian, all having different strikes or bearings. We must remember that the Menevian beds of North Wales rest (so far as is at present known) on the unfossiliferous Bangor, Llanberris, and Harlech grits throughout their known appearance and range.

Lower Cambrian Rocks.

The fossils which occur in the lowest known part of the Harlech and Bangor group at St. David's are *Lingulella ferruginea*, Salt., *L.*

* The Middle Cambrian or Lower Lingula-flags of Sedgwick, the Lingula-flags of authors, and the Upper Cambrian of Lyell and Salter; the Menevian group of Salter and Hicks.

primæva, Hicks, *Discina*, sp., *D. caerfaiensis*, Hicks, and *Leperditia cambrensis*, Hicks; these all occur in the lowest red shales below the sands at Castell, on the east side of Ramsey Sound. About 1000 feet of unfossiliferous red and purple grits and sandstones succeed this first known fossiliferous group; then, in yellowish-grey flaggy sandstones, between Porth-Clais Harbour and Caerbuddy, we meet, for the first time, with the gigantic Crustacea (Trilobita) *Plutonia* and *Paradoxides*, and associated with them two genera, *Microdiscus* and *Agnostus*, almost microscopic in size, and at the same time, or in the same beds, Protozoa belonging to two species of Hexactinellid sponges, *Protospongia fenestrata*, Salt., and *P. major*, Hicks, and also two species of Pteropoda, *Theca antiqua*, Hicks, and *T. penultima*, Salt. I particularly mention this first assemblage of life, as being, so far as I know, the *earliest in the earth's history on record*; and it consists nevertheless of forms whose organization was *not* embryonic; thus distinctly pointing to a line of ancestors belonging to this or some other area yet to be determined. The entire fauna of these *Plutonia*-beds consists of 8 genera and 9 species, 5 of which are Trilobita (viz. *Plutonia Segwickii*, Hicks, *Paradoxides Harknessii*, Hicks, *Conocoryphe Lydellii*, Hicks, *Microdiscus sculptus*, Hicks, *Agnostus cambrensis*, Hicks), two Protozoa (*Protospongia fenestrata*, Salt., and *P. major*, Hicks), with *Lingulella ferruginea*, Salt., and *Theca antiqua*, Hicks; three of these, *Paradoxides Harknessii*, *Agnostus cambrensis*, and *Protospongia fenestrata*, pass to the Menevian group. *Plutonia Sedgwickii*, *Conocoryphe Lyellii*, and *Microdiscus sculptus* have not been detected in any higher horizon, and *P. Harknessii* only in the succeeding red, grey, and purple flaggy sandstones, where it is associated with *Conocoryphe solvensis*, which represents *Conocoryphe Lyellii* below. Grey and purple sandstones, 1500 feet thick, but with a scanty fauna of only five species, including the doubtful *Eophyton*, succeed the *Plutonia*-sandstones. Finally the Harlech and Llanberris group at St. David's terminates with grey flaggy sandstones, which contain another form of *Paradoxides* (*P. aurora*), *Conocoryphe bufo*, Hicks, and *Agnostus cambrensis*, Hicks; in all eight species are known to occur.

This first incoming of life in the British rocks and in the St.-David's area exhibits a singular assemblage and grouping of species, doubtless owing to our limited acquaintance with the then existing fauna, rendered obscure through the present state of our collections. Numerically the fauna of the Lower Cambrian comprises 61 genera and 182 species, ranging from the lowest red shales of the Longmynd group to the top of the Tremadoc. The Longmynd and Harlech beds yield 18 genera and 32 species, the Menevian group of South Wales 24 genera and 51 species, the Lower Lingula-flags of all localities 17 genera and 36 species, the Upper Lingula-flags 14 genera and 41 species, the Lower Tremadoc 29 genera and 59 species, and the Upper Tremadoc 20 genera and 33 species. Of this Lower-Cambrian fauna (61 genera and 182 species) only 9 genera and 12 species pass to the Arenig; of these, 5 are Trilobita (*Asaphus affinis*, M'Coy, *A. Homfrayi*, Salt., *Cheirurus Frederici*, Salt., *Dionide atra*, Salt., and *Ogygia scutatrix*, Salt.). It will be observed that these are all Tremadoc species, none of the earlier or more pronounced Longmynd, Menevian, and Lingula-flag forms ever appearing above the Lingula-flags; but assuming that the Tremadoc rocks terminate the lower division of the Cambrian series, they must be acknowledged to be of value.

The species of Brachiopoda, as we should expect, tell much the same tale. They are *Lingulella primæva*, *L. ferruginea*, var. *ovalis*, and *Obolella maculata*, which do not pass out of the lowest divisions; while *Lingula petalon*, *L. lepis*, *Lingulella Davisii*, *Obolella plicata*, and *Orthis Carausii*, *O. lenticularis*, and *O. menapiæ* unite the Tremadoc to the Arenig. The remaining species are pelagic Mollusca. No Gasteropoda occur, and no form of Lamellibranch until we reach the Lower Tremadoc, where 12 species are met with, thus showing this earliest known fauna to have been highly specialized and of long duration; this would be expected from the great physical development of the rocks, as well as through the large crustacean fauna, which numbers 28 genera and 103 species, only 5 of which passed to the succeeding horizon, or the Arenig, as before stated; none of the great Olenidæ (*Paradoxides*, *Plutonia*, and *Neseuretus*) passes to the higher division of the Cambrian or Cambro-Silurian rocks.

The Pelagic fauna, 5 genera and 18 species, as exemplified by the Pteropoda and Heteropoda, was, and is still, the largest known, including *Cyrtotheca* 1 species, *Theca* 14, *Stenotheca* 1, *Conularia* 1, and *Bellerophon* 1. Nine of these are St.-David's forms; and only 2 species of Pteropoda, *Theca simplex* and *Conularia Homfrayi*, with *Bellerophon multistriatus*, pass to the Arenig; they will also be noticed under that group.

Plantæ.—Granting that the *Oldhamiæ* might be calciphites, or calcareous corallines, resembling in habit the *Melobesiæ* and *Nulliporæ* of modern seas, or the group of corallines so abundant in the seas of warmer latitudes, we are still at a loss as to their true nature, even if organic at all. Göppert refers them to sea-weeds, and compares *O. antiqua* with the living *Liagora ramellosa* of Kützing from Teneriffe; but Göppert makes two genera of *Oldhamia*; *Murchisonites* and *Oldhamia*, the *O. antiqua* of Forbes being his *Murchisonites antiqua*. Professor Kinahan and Edward Forbes both referred them to the class Hydrozoa as having affinities with the Sertulariidæ *. The Rev. Mr. Berkeley long ago suggested a resemblance to the genus *Acetabularia*, one of the Chlorospermeæ (Chlorosporeæ). No traces whatever of these singular remains have been found in any of the Cambrian rocks, either in North or South Wales. Mr. Salter well searched the Cambrian grits near Bangor and Harlech for *Oldhamiæ*; but nothing approaching them was ever detected. Probably their place, in the absence of better evidence, is amongst the Hydrozoa. It is singular that, amidst these grandly developed

* *Vide* Baily, 'Figures of Characteristic Brit. Foss.' vol. i. Palæozoic, p. 1, t. 1 (1875). This book should be in the possession of all students of Palæozoic palæontology.

rocks of Wales, both North and South, no traces of this doubtful body have occurred.

Protozoa.—Four species of Hexactinellid sponges (by no means uncommon in the Longmynd and Menevian rocks of St. David's) have been described. Three of the four species belong to the Harlech beds, below the Menevian; and all four occur in the Menevian. *Protospongia fenestrata*, Salt., is also from the Lower Lingula-flags proper. Zittel places these sponges in the family Euretidæ with the Hexactinellidæ, and in the group Dictyonina. Mr. Carter believes them to be the remains of sarco-hexactinellid sponges, which Mr. Sollas has confirmed*. Mr. Salter was the first to notice these Amorphozoa in the lowest and oldest rocks of Wales. The original form of these sponges we know not; it may have been flat and incrusting, like *Grantia*. Mr. Sollas suggests that they may have been "sacciform" and anchored in the slimy ooze of the sea-bottom by a tuft of anchoring-spicules†. The spicules were originally siliceous, but are now converted into iron pyrites. The fact also that the spicules are separate, not being "enveloped in a common coating, or united by ankylosis, clearly places or assigns them to the group Lyssakina of Zittel, nearly equivalent to Carter's division of the Sarco-hexactinellidæ." The species known are *Protospongia diffusa*, Salt., *P. fenestrata*, Salt., *P. major*, Hicks, and *P. flabellata*, Hicks. No traces of these have occurred either in the Harlech, Longmynd, Menevian, or Lingula-flags of North Wales. They may be sought for round the Harlech Dome, amidst the black shales and flags of the Menevian beds.

Annelida.—The Longmynd group yields four genera and five species, *Arenicolites uricomiensis*, Call., *A. sparsus*, Salt., *Scolites socialis*?, *Haughtonia pœcila*, Kin., and *Histioderma hibernica*, Kin. If the quartzites of the Wrekin in Shropshire are of the age assigned to them by Dr. Calloway, then the *Arenicolites uricomiensis* of that author is, with the exception of *Eozoon canadense*, the oldest known fossil. Beyond the doubtful Annelidan tracks, and one species (*Arenicolites sparsus*) from the Longmynd group of England and Wales, we have no determined species. Two of the five species (*Haughtonia pœcila*, Kin.) and *Histioderma hibernica*, Kin., are Irish, from near Bray Point. Nine out of ten of the so-called fucoidal or plant-remains in the rocks below the Devonian are only Annelide-burrows.

Crustacea.—Seven genera and 14 species occur in the lowest Cambrian or Harlech rocks of St. Davids, 10 of which are confined to them; the remaining 4 species (*Agnostus cambrensis*, *Conocoryphe bufo*, *Paradoxides aurora*, and *P. Hicksii*) connect the Harlech and Longmynd Crustacea with the Menevian. The 7 genera are *Agnostus*, *Conocoryphe*, *Leperditia*, *Microdiscus*, *Paradoxides*, *Plutonia*, and *Palæopyge*: 2 species of *Conocoryphe* (*C. Lyellii* and

* See Quart. Journ. Geol. Soc. vol. xxxvi. pp. 362–367, Sollas "On the Structure and Affinities of the Genus *Protospongia*."

† This has been confirmed through the occurrence of another form in the same family, lately described by Mr. Sollas from the Silurian of Canada.

C. solvensis), 3 species of *Leperditia* (*L. ferruginea*, *L. cambrensis*, and *L. primæva*), *Microdiscus sculptus*, and *Plutonia Sedgwicki* are all confined to the Harlech and Llanberris group of St. David's. They constitute the Crustacean fauna of that horizon, out of 103 species known in the six divisions of the Lower Cambrian rocks, and up to the close of the Upper Tremadoc. The Menevian group possesses the largest Crustacean fauna in the eleven classes, and, except the Brachiopoda, the largest number individually.

Hydrozoa.—No form known below the Upper Lingula-flags or the Lower Tremadoc, from which Dr. Callaway has obtained the earliest known species, *Bryograptus Callavei*, Lapw. Mr. Lapworth's genus occurs in the Shineton shales of Shropshire. The same genus occurs in the *Olenus*-beds of Westrogothia, in Sweden, Linnarsson having detected these oldest Rhabdophora in that area.

Brachiopoda.—Only 6 species are essentially Lower-Cambrian or Harlech forms, *Discina pileolus*, *D. caerfaiensis*, *Lingulella ferruginea* and var. *ovalis*, *L. primæva*, and *Orthis sagittalis*; this last species is doubtful. Five genera and 20 species range through the six horizons, or from the Longmynd group to the Upper Tremadoc; but, as we have seen, only the 6 just named occur in the lowest horizon; 4 of these belong to the Tretenterata (non-articulate group). It is doubtful if the others occur in the Longmynd group.

Lamellibranchiata.—No bivalve mollusk is known to occur below the Lower Tremadoc. In that formation for the first time in Britain we recognize 5 genera with 12 species. *Davidia* and *Glyptarca* are new; the remaining 3 are the well-known genera *Modiolopsis*, *Palæarca*, and *Ctenodonta*. This may be regarded as the first well-determined appearance of the Pelecypoda in any region.

Gasteropoda.—None known in the whole of the series of formations below the Arenig, where four genera seem to be recognized, both in South Wales (St. David's) and in the Stiper-stones area. *Pleurotomaria llanvirnensis*, Hicks, *Euomphalus corndensis*, Sow., and forms of *Ophileta* and *Rhaphistoma* occur.

Pteropoda.—The six horizons of the Lower Cambrian yield 4 genera, *Cyrtotheca*, *Stenotheca*, *Theca*, and *Conularia*, and are represented through the six divisions by 11 species: but only 2 occur in the Longmynd group of St. David's under analysis (*Theca antiqua*, Hicks, and *T. penultima*, Salt.). The Menevian beds of the same area have yielded 6 species, to be noted under that group of rocks, and the Lower and Upper Tremadoc 9 species. During the Arenig and Caradoc periods only, have we to record so many pelagic Mollusca; 8 species occur in the Arenig, and 10 in the Caradoc.

Heteropoda.—*Bellerophon* is the only form that occurs in these lowest rocks; but no species has been recorded lower than the so-called Middle Lingula-flags, where, as *B. cambrensis*, Belt, the genus first appears, associated with *Hymenocaris vermicauda* and *Conocoryphe* in the Upper Ffestiniog rocks; but four of the five known species are Tremadoc, where, specifically, the genus becomes of importance. *B. multistriatus*, Salt. (an Upper-Tremadoc species), unites the Heteropoda of the Lower with those of the Arenig or Middle Cambrian group.

Cephalopoda.—No form or species known until we reach the horizon of the Tremadoc rocks, where for the first time we find both *Cyrtoceras* and *Orthoceras*, one species of each genus. *Cyrtoceras præcox*, Salt., is, I believe, the earliest Cephalopod known. The Lower Tremadoc rocks of Llanerch, west of Portmadoc, yielded the *Cyrtoceras*; and the Upper Tremadoc of Garth, and Llanvirn, St. David's, *O. sericeum*. The latter passes to the Arenig rocks.

We have thus seen how unequally distributed (as we should expect) are the zoological groups through the lowest Cambrian rocks, and how distinctively certain genera characterize them, and, as will be found upon a separate analysis of the Menevian, Lingula-flags, and Tremadoc beds, how distinct a period is represented by all below and up to the close of the Tremadoc age. The six divisions of the Lower Cambrian represent the earliest history of the British rocks; for out of the 61 genera and 182 species known to range through them, only 11 genera and 16 species pass to the Arenig or base of the Lower Silurian, or Middle Cambrian (see Table VII.).

Table I.—*Longmynd, Harlech, and Llanberris.*

Classes.	Genera.	Species.	Pass to Menevian.
Plantæ	2?	3?	
Protozoa	1	3	1/3
Hydrozoa.			
Actinozoa.			
Echinodermata.			
Annelida...	4	4	
Crustacea	7	14	3/4
Bryozoa.			
Brachiopoda	3	6	3/4
Lamellibranchiata.			
Gasteropoda.			
Pteropoda	1	2	1/1
Heteropoda.			
Cephalopoda.			
	18	32	8/12

Dr. Hicks has favoured me with a new classification for the Lower Cambrian (Longmynd and Harlech) rocks of St. David's: the geographical significance of the names employed renders them of value; and nothing of the kind has been previously attempted below the Menevian group:—

Menevian group.	Upper, 100 ft.	Sandstones and shales, with *Orthis Hicksii* &c.
	Middle, 350 ft.	Flags and slates, with *Paradoxides Davidis.*
	Lower, 300 ft.	Grey flags, with *Paradoxides Hicksii* &c.
Solva group.	Upper, 150 ft.	Grey rocks, with *Paradoxides aurora* &c.
	Middle, 1500 ft.	Grey, purple, and red rocks, with *Paradoxides solvensis* (Hicks, MS.), *Conocoryphe solvensis*, &c., also *Eophyton* and large fucoids.
	Lower, 150 ft.	Yellowish grits, sandstones, and flags, with *Paradoxides Harknessii, Plutonia Sedgwickii*, &c., also *Eophyton.*
Caerfai group.	Upper, 1000 ft.	Purple sandstones, with Annelids.
	Middle, 50 ft.	Red shales and schists, with *Leperditia cambrensis, Lingulella primæva, Discina caerfaicnsis* (Hicks, MS.), &c.
	Lower, 520 ft.	Conglomerates and green flaggy sandstones, with Annelids.

Below the Caerfai group in South Wales, at St. David's, occur the Dimetian and Pebidian rocks, Pre-Cambrian in age, unconformable in position, and discordant in strike; they constitute the well-defined axis of the St.-David's promontory.

Menevian* and Lingula-flags.

In 1865 Messrs. Salter and Hicks gave the name to and established this group of strata in the St.-David's promontory, Pembrokeshire†; it constitutes the lowest division of the Middle Cambrian of Sedgwick, and equals his Lower Lingula-flags, and is embraced in the Lingula-flags of authors and the Upper Cambrian of Lyell and Salter; it is also recognized as being equivalent to Barrande's Étage C in Bohemia; it occurs in Sweden, has been recognized in North America and Canada, and is the St.-John's group in Newfoundland.

The Menevian is now recognized as a separate division or subgroup, distinguished from the Lingula-flags proper above, as the Ffestiniog of Sedgwick was applied to the Middle and Upper groups of the Lingula-flags in North Wales. In South Wales the Menevian is about 700 feet thick, and more or less fossiliferous throughout. Probably the base of the Menevian cannot be separated from the underlying grits and sandstones of the Harlech and Bangor series, passing as they insensibly do into them, both in North and South Wales, and also into the true Lingula-flags above. No fossils occur or have yet been detected in the grits and sandstones of the immediately underlying Harlech rocks, which comprise the structure of the Harlech Dome (Merionethshire anticlinal of Sedgwick); the same may be said of the great and exposed masses of these Lower Cambrian rocks of the Bangor area, obscure traces of Annelide-

* Menævia is the classic name for St. David's.

† First announced at the British Association, Birmingham, 1865, 'Report,' p. 281.

tracks (*Chondrites*) and burrows (*Arenicolites*) being all that has rewarded patient research; but below the primordial Menevian, as we have seen, in the promontory of St. David's, there exist greenish, grey, and red flaggy or shaly sandstones, with species of *Lingulella* differing from the typical *L. Davisii* of succeeding age. In the yellow, grey, and purple sandstones and flags we have the first known Trilobites; and these are of gigantic size—the two genera *Plutonia* and *Paradoxides*, with *Conocoryphe*, demanding from us the belief that they were by no means the first of Cambria's Crustacea.

The earlier highly metamorphosed rocks below the Caerfai group and the *Plutonia*-sandstones in all probability contained the progenitors of these early giants; nowhere else in the British islands, Europe, or America have species been found of such high antiquity. To the untiring energy of Dr. Hicks we owe the discovery of these rocks and the description of the species contained in them.

The Menevian of the St.-David's area rests upon and passes insensibly down into the fossiliferous Harlech and Bangor rocks, which contain an earlier fauna, which is not at all represented in North Wales, either at Harlech or Bangor. Only one of the five species of the great *Paradoxides* found in the pre-Menevian and Menevian beds of South Wales is known in North Wales. The long-known and solitary specimen called *P. Forchhammeri*, from an unknown locality, is now determined to be *P. Hicksii*, which occurs sparingly in the Menevian beds on the Camlan river north of Dolgelly, but more abundantly with its two congeners, *P. aurora* and *P. Davidis*, in South Wales, the fourth species, *P. Harknessii*, characterizing only the Harlech group at St. David's *. Associated with these large Menevian *Paradoxides*, other forms, equally significant, occur, viz. *Holocephalina inflata*, Hicks, *H. primordialis*, Salt., and *Carausia menevensis*, Hicks; and they range no higher, being distinctively typical or characteristic species of this horizon.

Two species of *Anopolenus* (*A. Henrici*, Salt., and *A. impar*, Hicks) are common to the two areas, the former occurring at Rhaidr-ddu valley, Tyddyngwladis, near Dolgelly, the latter at the Maentwrog Waterfall.

No less than 6 species of the genus *Conocoryphe* occur in the Menevian group: 3 characterize the St.-David's, and 2 the North-Wales beds; and 1 species, *C. applanata*, is common to both areas. *Conocoryphe humerosa*, Salt., *C. bufo*, Hicks, *C. solvensis*, St. David's only; *C. coronata*, Barr., *C. Homfrayi*, Salt., North Wales, Maentwrog; *C. applanata* uniting the two areas. *Erinnys venulosa*, Salt., and *Arionellus longicephalus*, Hicks, are both found in the Waterfall-valley at Maentwrog, and the latter also at St. David's. I draw attention to this group of Crustacea because they are stratigraphically important, and constitute by far the most characteristic

* Dr. Hicks has added another species from the Trelewr beds below the Menevian, *P. solvensis*, associated with *Conocoryphe solvensis* and the so-called *Eophyton*.

portion of the fauna of the lowest Cambrian rocks. No less than 9 genera and 26 species occur in the Menevian rocks alone of North and South Wales; or, in other words, more than half the known fauna is Trilobitic. In the Menevian beds occur the first known Cystidean, a few fragments having been found by Dr. Hicks, in 1872, associated with Pteropoda (*Theca*) and Entomostraca. The finding of *Paradoxides Davidis* and *P. Hicksii* at Dolgelly, on the same horizon as that of St. David's, immediately above the "Cambrian" sandstones (Harlech and Barmouth beds), in bands of uncleaved Menevian slate and ashes, aids greatly in the correlation of the two areas. This, with other evidence, justified Hicks and Salter in regarding the Menevian and the Lower Lingula-flags as a well-marked division or subgroup differing from the Upper Lingula-flags, quite as much so as do the Upper Lingula-flags from the overlying Lower Tremadoc slates (as now understood); for, with few exceptions, the species in each are peculiar, and they possess many peculiar genera. I may mention the following as genera that first appear in the Menevian beds; and those marked with an * are confined to that horizon:—

Cystidea	**Protocystites*.
Annelida	**Arenicolites*.
Crustacea	**Arionellus*.
,, ...	**Anopolenus*.
,, ...	**Erinnys*.
,, ...	**Holocephalina*.
,, ...	**Carausia*.
,, ...	*Primitia*.
Brachiopoda	? *Orthis*.
,, ...	*Obolella*.
Pteropoda..........	**Cyrtotheca*.
,, ...	**Stenotheca*.

Although four species of Protozoa (*Protospongia diffusa*, Salt., *P. fenestrata*, Salt., *P. major*, Hicks, and *P. flabellata*, Hicks) occur at St. David's, the three first named species commenced in the Harlech beds below, *P. flabellata* being Menevian only.

No Protozoa have yet been detected in the North-Wales area. Prior also to the year 1863 we had no knowledge of the existence of the gigantic *Oleni*, revealed to us by the researches of Salter, who disentombed the great *Paradoxides* (*P. Davidis*) from the black slates of Porth-y-rhaw and Solva Harbour, thus showing the occurrence side by side in the same beds of the largest Trilobite known with *Agnostus* the smallest. Both these genera are remarkable; and their extremes widely depart from the general type.

A valuable paper was communicated to our Society in 1867, vol. xxiii., by Prof. Harkness and Dr. Hicks, "On the Ancient Rocks of St. David's Promontory, South Wales, and their Fossil Contents." The authors dealt fully with both the geology and the palæontology of that remarkable promontory. The chief portion of the labour and research, however, was due to Dr. Hicks, whose intimate acquaintance with the area and knowledge of the fauna of the Cambrian and Silurian rocks enabled him to add largely to the palæontology of the district. The authors described the great series of red, purple, green, and grey rocks below the fossiliferous grey Menevian beds. The history of these variously coloured sandstones, as revealed by the researches already made in them, has an important bearing upon our knowledge of the distribution of life through the Cambrian and Silurian series of North Wales, with which they must be correlated, the St.-David's series yielding a fauna not yet known in Monmouthshire, Caernarvonshire, or Montgomeryshire, or beneath the Menevian and Lingula-flags of North Wales, which contain organic remains older than, and different in species from any hitherto discovered in Britain. The underlying Cambrians repose upon a conglomerate, composed of quartz and other pebbles cemented in a purple or red arenaceous matrix, which occurs on both sides of the so-called Pre-Cambrian ridge or axis. That this quartziferous, metamorphosed, crystalline, and unconformable mass underlies and is older than the whole series of the Lower Cambrian rocks of that area is certain; and, as such, it is the key to the physical structure of the ancient headland of St. David's. Subsequent research by Hicks has determined that this extensive and exposed Pre-Cambrian area is composed of three distinct groups of metamorphosed sedimentary rocks of different ages, and having different or discordant bearings or strikes*. Higher still, and also unconformably, succeed the rocks of the Harlech or Longmynd group, which lie both to the east and west. Until the Longmynd, Harlech, and Menevian fauna was discovered and worked out at St. David's, and the last named subsequently developed in North Wales, the lowest sedimentary rocks of Britain then known were believed to be almost devoid of life or "barren in fossils." Now, however, a remarkable fauna has rewarded the researches of many distinguished labourers, and the two areas have been carefully compared and correlated. Considerable differences exist, of which the causes are as yet unknown; much has yet to be done in the palæontology of both these classical districts. The non-discovery or absence of the genus *Olenus* in the Menevian and Lingula-flags or primordial rocks of St. David's is singular, and at present inexplicable. The genus is abundantly represented in both the Lower and Upper Lingula-flags of North Wales, where no less than 12 species are known, 4 in the lower division and 8 in the upper; and 4 distinct forms (viz. *O. bisulcatus*, *O. scarabæoides*, *O. humilis*, and *O. pauper*) occur in the Upper Lingula-flags of Malvern, overlying the Hollybush sandstones. The species *O. scarabæoides* (*O. spinulosus*, Phill.) is found also in the Upper Lingula-flags of Carreg-Wen, west of Portmadoc.

Comparison of the earliest known faunas in Europe and America with that of St. David's shows conclusively that they are identical as to age or time of deposition and in genera also. This Angelin has

* See p. 56 *et seq.*

demonstrated through his researches into the alum shale of Sweden; and the primordial fauna of Barrande has yielded *Paradoxides*, *Conocoryphe*, *Agnostus*, and *Ellipsocephalus*, the first three of which are characteristic British genera.

Sweden has afforded *P. Hicksii* and other forms like our own.

The Spanish primordial rocks yield genera identical with those of our Menevian and Lingula-flags—*Paradoxides, Conocoryphe, Arionellus*, and *Agnostus*. America, has its Acadian group, with *Paradoxides* &c. The Protozoic schists of Bohemia (Region C, Barrande), also contain *Paradoxides* (*P. bohemicus*), *Sao*, *Conocoryphe*, and *Agnostus*. The same conditions prevail in Canada and New Brunswick. It would thus appear that all the regions in Europe and America north of 30° of latitude to the polar regions contain these primordial rocks and fossils.

I regard the Menevian of St. David's as being the most typical, as regards both physical development and the abundance of organic remains (individually and specifically). The intricacy of the geological structure of North Wales renders both the mapping and the collecting of fossils in the Menevians there far more difficult than in the St.-David's promontory, the strike of the beds being more disturbed in continuity; but I doubt not that an extensive fauna is yet to be obtained from the Menevian of North Wales, where the typical Lower Lingula-flags mantle round the still older Cambrian masses.

The palæontological value of any group of rocks can only be arrived at through such analysis as I have here attempted to give; it is the census at a given time or age, and from such may be cast or determined (approximately) the true and absolute value of the zoological groups and their distribution through their respective formations.

Plantæ.—No traces whatever of plant-remains have occurred in the Menevian.

Protozoa.—The St.-David's beds of this age contain all the known 4 species of *Protospongia*, viz. *P. diffusa*, *P. fenestrata*, *P. major*, and *P. flabellata*, the first three of which, as we have seen, are also Longmynd and Harlech forms. At St. David's *P. fenestrata* passes to the Lower Lingula-flags proper. None have occurred either in the Menevian or Lingula-flags of North Wales.

Hydrozoa.—No traces.

Actinozoa.—Totally unrepresented.

Echinodermata.—Cystidean remains were detected by Mr. Salter in 1866 at St. David's; to these he gave the generic name *Protocystites*. Dr. Hicks subsequently named these fragments *P. menevensis*, after the horizon in which they occur. These obscure fossils consist of arm-ossicles and body-plates; it is the first Cystidean recorded. Dr. Hicks has also determined the presence of *Dendrocrinus cambrensis* in the Tremadoc rocks of St. David's, the oldest Crinoid known in the British rocks.

Annelida.—*Arenicolites didymus*, Salt., *A. sparsus*, Salt., and *Serpulites fistula*, Hall, appear to be all that are known of the Anarthropoda in the Menevian beds. The first two are confined to this horizon; *S. fistula* passes to the Upper Lingula-flags.

Crustacea.—The largest crustacean fauna of the six divisions of the lowest Cambrian rocks occurs here. 12 genera and 32 species characterize the Menevian beds both of North and South Wales. *Agnostus* is represented by 7 species, *Anopolenus* by 3, *Conocoryphe* by 7, *Paradoxides* by 3, *Holocephalina* by 2, and *Leperditia* by 4 species. These 6 genera are the chief and most largely represented. *Arionellus*, *Erinnys*, *Microdiscus*, and *Carausia*, each with one species, are confined to the Menevian beds, and generically characterize them. The black slaty flags of St. David's yield the gigantic *Paradoxides P. aurora*, Salt., *P. Davidis*, Salt., and *P. Hicksii*, Salt.; this last-named species has been recorded from the Lingula-flags of North Wales under the name *P. Forchhammeri*. 14 of the 32 species pass to the Lower Lingula-flags, but none higher; and the Menevian beds are connected below with the Harlech beds and the Longmynd group through 4 species only, viz. *Agnostus cambrensis*, Hicks, *Conocoryphe bufo*, Hicks, *Paradoxides aurora*, Salt., and *P. Hicksii*, Salt. No *Oleni* occur in the Menevian rocks, although 13 species belong to the Lingula-flags proper. *Olenus* is essentially an Upper Lingula-flag genus, 9 species occurring in that series; and none pass out of the Lower Cambrian rocks or above the Tremadoc group, where 4 species occur (*O. alatus*, *O. impar*, *O. triarthrus*, and *O. Salteri*).

Bryozoa.—No remains of this class occur in the Menevian; they first appear in the Upper Lingula-flags under the form of *Dictyonema*?

Brachiopoda.—Only 4 genera and 6 species range through the Menevian beds, *Orthis Hicksii*, Salt., being the only peculiar form. *Lingula ferruginea*, Salt., and var. *ovalis*, Hicks, *Obolella maculata*, Hicks, *Discina pileolus*, Hicks, and *Orthis sagittalis*, M'Coy, are associated either with the Harlech beds below or the Lower Lingula beds above. Every species occurs in the St.-David's Menevian beds. It is not until we rise into the Llandeilo and Caradoc rocks that the class becomes numerically so distinguished and important a factor in the Cambrian or Silurian rocks.

Lamellibranchiata.—No form known in the Menevian beds.

Gasteropoda.—No vestige known in the British rocks of this age.

Pteropoda.—*Cyrtotheca hamula*, Hicks, *Stenotheca cornucopia*, Salt., *Theca corrugata*, Salt., *T. penultima*, Salt., *T. menevensis*, Salt., and *T. stiletto*, Salt., or 3 genera and 6 species, are known. 4 of the 6 species are Menevian only, viz. *C. hamula*, *S. cornucopia*, *T. menevensis*, and *T. stiletto*. *T. corrugata* is the only form that passes to the Lower Lingula-flags above.

Heteropoda.—None known in the Menevian of either South or North Wales.

Cephalopoda.—No species has yet occurred in the British rocks of this horizon, the only two species in the Lower Cambrian being those before mentioned, *Cyrtoceras præcox* and *Orthoceras sericeum*, both of which are Tremadoc.

Thus we see that, out of the 52 species that constitute the fauna of the Menevian rocks, 32 are Crustacea—the only other classes fairly represented being the Brachiopoda, 6 species, and the Pteropoda, 6 species. A marked feature is the appearance of Cystidea (*Protocystites*) and Crinoidea (*Dendrocrinus*). Eight whole classes are entirely unrepresented: the Plantæ, Hydrozoa, Actinozoa, Bryozoa, Lamellibranchiata, Gasteropoda, Heteropoda, and Cephalopoda are all absent. The genera that first made their appearance in the British Menevian sea were *Protocystites, Dendrocrinus, Serpulites,* 7 Crustacea (*Holocephalina*, *Entomis*, *Anopolenus*, *Arionellus*, *Leperditia*, *Erynnis*, and *Carausia*), *Orthis* among the Brachiopoda, and 2 Pteropoda (*Cyrtotheca* and *Stenotheca*). The other genera appeared for the first time in the lowest Cambrian of the St.-David's promontory.

Table II.—*Menevian.*

From the Longmynd rocks.	Classes.	Genera.	Species.	Pass to Lower Lingula.
	Plantæ.			
$\genfrac{}{}{0pt}{}{1}{3}$	Protozoa	1	4	$\genfrac{}{}{0pt}{}{1}{1}$
	Hydrozoa.			
	Actinozoa.			
	Echinodermata......	1	1	
	Annelida	3	3	
$\genfrac{}{}{0pt}{}{3}{4}$	Crustacea	12	32	$\genfrac{}{}{0pt}{}{8}{14}$
	Bryozoa.			
$\genfrac{}{}{0pt}{}{3}{4}$	Brachiopoda.........	4	6	$\genfrac{}{}{0pt}{}{3}{3}$
	Lamellibranchiata.			
	Gasteropoda.			
$\genfrac{}{}{0pt}{}{1}{1}$	Pteropoda............	3	6	$\genfrac{}{}{0pt}{}{1}{1}$
	Heteropoda.			
	Cephalopoda.			
$\genfrac{}{}{0pt}{}{8}{12}$	....	24	52	$\genfrac{}{}{0pt}{}{13}{19}$

Lingula-flags.

The fossiliferous strata lying both above and below the Lingula-group have of late years been well described and their fossil contents marked out, the fauna of each group carefully investigated, compared, and catalogued. The Harlech and Llanberris and also the Menevian beds of South Wales have been exhaustively illustrated by Hicks and Salter. Upon the Tremadoc group, in North Wales, the labours of Mr. Homfray, Mr. Ash, and the late Mr. Salter leave little to be done; subsequently Dr. Hicks investigated the Tremadoc and Arenig groups in the St.-David's promontory, with what success I hope to show. It must not be forgotten that since the Geological Survey (thirty years ago) mapped much of North and

South Wales, a great amount of new work has been done by eminent geologists and palæontologists. Much of the work done by the Survey has had to be readjusted and reconstructed; the maps then prepared with so much skill by Ramsay, Selwyn, Jukes, Aveline, and others, and which contributed so much to our knowledge, and to the elucidation of the structure of these intricate regions, are now in some areas behind the requirements of the age, through the progress of modern research and nomenclature. The horizons of many of the lowest fossiliferous groups of rocks as now recognized are not expressed or delineated on the Survey maps; the now well-determined Menevian, Tremadoc, and Arenig rocks of North and South Wales—in other words, all the fossiliferous deposits below the Llandeilo flags, or between that formation and the base of the Tremadoc, are not yet delineated on the maps of the Survey. It may be said by some that the groups of the Harlech, Menevian, and Lingula-flags may be subdivided and placed upon the Survey maps; but the aspect of these beds and the way they occur in the field will ever prevent this on a 1-inch scale. Transcendentalism in mapping has been, and still is, carried to a greater extent and perfection by the officers of the British Survey than by any other government survey in the world; and although neither the Tremadoc nor Arenig rocks are recognized on the maps of the Survey, I believe it will be found that these formations have received the fullest recognition and attention in the forthcoming new edition of Prof. Ramsay's 'Geology of North Wales.'

The Lingula-flags of the Survey and authors generally are equivalent to the Middle Cambrian of Sedgwick, and the Upper Cambrian of Lyell and Salter; the divisions into Lower, Middle, and Upper have long troubled systematists in Britain; and the extensive and almost hypercritical subdivisions adopted have led to much misunderstanding. The obscurity of these beds in the field, the smallness of the fauna, and the difference in physical condition in areas widely separated often render it a matter of opinion where the lines of demarcation should be drawn, or what should be embraced by the terms Lower, Middle, and Upper Lingula-flags. The so-called Middle group has no value whatever, its fauna consisting of five species only. Three of these are Brachiopoda—*Kutorgina cingulata*, *Lingulella Davisii*, and *Lingula squamosa*. There is one Trilobite (*Conocoryphe? bucephala*, Belt), and also *Bellerophon cambrensis*, Belt. These last two forms occur in the upper part of the Dolgelly beds of that area, and are said to have been associated with *Hymenocaris vermicauda*, elsewhere known only in the Lower Lingula-flags.

We must also remember that the "Lower Lingula-flags" of Sedgwick are the "Menevian group" of Salter and Hicks, and that the "Ffestiniog group" of Sedgwick constitutes the Middle and Upper Lingula-flags of Salter. Thus the greatest care is required when analyzing or correlating these groups, either through their literature or by research in the field. In the year 1867 the late Mr. Belt* con-

* Geol. Mag. vol. iv.

tributed much to our knowledge of the fauna and geology of the Lingula-flag series. He was then engaged in investigating the Dolgelly and other districts, especially with reference to the divisions of the Lingula-flags called the Maentwrog, Ffestiniog, Dolgelly, and Tremadoc groups, lying between the Menevian and Tremadoc beds, and occupying extensive areas near Dolgelly and in the Mawddach valley, also at Maentwrog near Ffestiniog &c.

In 1847 Prof. Sedgwick, on palæontological evidence, removed the previously named Tremadoc series from the "Lingula-flags," and designated the latter the Ffestiniog group. Salter divided the Lingula-flags, in 1866, into Lower, Middle, and Upper. Again, Salter and Hicks, in the same year *, included the Lingula-flags of South Wales only in the Ffestiniog group, describing them as being characterized by "hard siliceous sandstone with grey flaky slate" containing "*Lingulella Davisii.*" In character the North-Wales group of rocks differs altogether from those of South Wales, the arenaceous flags and shales with *L. Davisii* forming only a subordinate part of a series of fine-grained dark blue and black slates containing many genera of Trilobites. Mr. Belt restricted the Ffestiniog beds to the flags containing *Lingulella Davisii* and the Phyllopod Crustacean *Hymenocaris vermicauda*, as originally applied by Sedgwick, and proposed to name the slates and flags below them the Maentwrog group, characterized by peculiar *Oleni*. These Maentwrog beds are exhibited to great perfection at Maentwrog, S.W. of Ffestiniog.

The blue and black slates occurring above the Ffestiniog series Belt named the Dolgelly group, with reference to the circumstance that it is only in this area that both members have been found. This upper member of the Lingula-flags is characterized by peculiar forms of *Oleni*, comprising the subgenera *Sphærophthalmus*, *Parabolina*, &c. These three groups—the Maentwrog, Ffestiniog, and Dolgelly—are palæontologically and lithologically distinct; none of the Trilobita passes from one group to another, peculiar genera occurring in each. Each group also has well-defined lithological characters. The Maentwrog is readily distinguished by its dark-blue jointed ferruginous slates; the Ffestiniog by hard micaceous flags with abundant *Lingulella Davisii*, *Hymenocaris*, and *Conocoryphe*; and the uppermost or Dolgelly, by species of *Agnostus*, *Olenus* and its subgenera, which are abundant in the soft black slate, which shows a black streak when scratched. Mr. Belt divided the Maentwrog slates into a lower and upper series: the lower are ripple-marked, and have many Annelide-tracks. They are conformable to the blue-black Menevian slates which mantle round the Merionethshire anticlinal. This lower group is about 700 feet thick. *Olenus gibbosus*, Wahl., and *Agnostus pisiformis*, Linn. (*A. princeps*, Salt.), var. *obesus*, Belt, occur in the slates. The range between the Eden and the Mawddach, and near Dolmelynllyn, in the Mawddach, are the chief localities for fossils. The upper Maentwrog series is nearly 2000 feet thick. *Agnostus princeps* is abundant in the flaky

* Brit. Assoc. Reports, 1866.

beds near the summit above Dolgoed ; in thin slaty shales it occurs in thousands, associated with *Olenus truncatus*, Ang. ; the higher beds contain *O. cataractes*, Salt., which replaces *A. princeps*. This group is completely developed in the Maentwrog district, fine sections occurring in the Waterfall valley and in the valley running from Taffarn-helig to Caen-y-coed. *Olenus cataractes* abounds here.

Lower Ffestiniog Beds.

Thick micaceous grey flags, 2000 feet thick, conformably overlie the upper Maentwrog beds; the lowest series are bluish-grey slates, and contain *Lingulella Davisii*, M'Coy, with Annelide-tracks ; and the highest part of the Lower Ffestiniog slates yields *Hymenocaris vermicauda*, only known in this division of the Lingula-flags.

Upper Ffestiniog.

This group succeeds the Lower series, and is not more than 50 feet thick, but distinct in fossil contents. The characteristic forms here are *Olenus micrurus* and *Bellerophon cambrensis*. This thinly developed division occurs at Gwern-y-barend, in the Mawddach near Craig-y-dinas and on Mynydd-Gader.

The river Mawddach cuts through the whole of these beds between Rhiufelyn and Hafod-fraith, thence ranging across the east end of Moel Hafodowen and by Pen-y-bryn.

Dolgelly Group.

This uppermost division of the Lingula-flags is physically divided into two series, lower and upper, the former composed of hard blue slates abundantly filled with *Olenus* (*Parabolina*) *spinulosus*. The thickness of this series is about 300 feet.

The upper division differs essentially from the lower. It consists of soft black slates, with black streak, intensely cleaved and often pisolitic (fine grains of pisolitic iron-ore). The constant character of the black streak distinctively marks this group, and in the most disturbed areas may be relied on as a never-failing criterion of the upper series. To Mr. Belt is due the determination of this character over a large area—a fact of inestimable value in the identification of strata so disturbed and intricately faulted as those round Dolgelly, Rhobell-fawr, and on Mynydd-Gader. The black shales of Malvern, overlying the Hollybush Sandstones, and containing *Olenus bisulcatus*, Phill., *O. scarabœoides*, Wahl., *O. pauper*, *O. humilis*, *Conocoryphe malvernensis*, *Agnostus princeps*, *A. M'Coyi*, &c., belong here ; they underlie the *Dictyonema*-shales, and are exposed in the valley of the White-leaved Oak. The upper Dolgelly beds are by far the most fossiliferous ; and nearly every species in any of the areas is confined to this division. The Trilobites in the Dolgelly area are *Conocoryphe abdita*, Salt., *C. Williamsonii*, Belt, *C. longispina*, Belt, *Olenus scarabœoides*, *Sphœrophthalmus* (*Olenus*) *alatus*, *S.* (*Olenus*) *humilis*, Phill., *Agnostus princeps*, Salt., *A. trisectus*, Salt., and *A. obtusus*, Belt; and, as before stated, the Malvern species are equally restricted. No one of these occurs below in the Middle and Lower Lingula-flags. *Orthis lenticularis*, Dalm., and *Obolella* follow the same rule all through the Maentwrog, Ffestiniog, and Dolgelly deposits; the Trilobita that successively appear are closely allied, or belong to the Agnostidæ and Olenidæ; no new types of structure come in, the fauna being distinctive and similar and homogeneous as a whole. *Dikelocephalus*, *Conocoryphe*, *Olenus*, and *Paradoxides* constitute the natural group or family Olenidæ; and the single genus *Agnostus* is rich in species. The succeeding Tremadoc and Arenig rocks evidence great and sudden change, faunal and otherwise, the large Asaphidæ, Cheiruridæ, Trinucleidæ, and Calymenidæ then first appearing; sixteen genera at once occur in the Arenig, and two in the Tremadoc (*Niobe* and *Psilocephalus*); and we have no proof of any unconformity in either the North or the South Wales areas: these large forms come in at once and in vast numbers; and the old forms die out. Nor have we as yet any evidence of these new and distinct types having had prior existence in some other area, and migrated into the Tremadoc or Arenig seas; we know not at present where to look for evidence of this. Ireland possesses no rocks or fossils of this age or earlier, Scandinavia none, Western Europe none. America then possessed gigantic *Asaphi*; but in which direction dispersion or distribution may have taken place we have no trace; although the evidence tends to show that it must have been towards the east, or Europe, the main strike of the oldest American rocks being N.E. and S.W.; while the older groups are greatly developed on the eastern side of the North-American continent, and there is considerable affinity between the faunas of the two areas, the facies strongly resembling each other. No migration of an earlier fauna from one area would fully account for the disappearance of the earlier gigantic Trilobites (such as *Paradoxides*, *Plutonia*) and other equally characteristic genera (such as *Erinnys*, *Holocephalina*, &c.), all of which characterize the lowest rocks of Britain, ranging from the Harlech to the top of the Lingula-flags, call them what we will.

Salter, as far back as 1853, most carefully described the two groups (Lower and Upper) of the Lingula-flags in North Wales; he examined them in their most typical localities, selecting Maentwrog, Tremadoc, Ffestiniog, Dolgelly, Carnedd Ffiliast, Bangor, &c. as those places where the Lower division could be best studied. This he divided into two sections, the lowest consisting of black pyritous slates, with numerous beds of intercalated sandstones near the base. These probably in part were Menevian; but the prevailing fossils are *Agnostus princeps*, *Olenus cataractes*, and *Lingulella Davisii*. (Salter's species *A. princeps* is the *A. pisiformis*, Linn., of the Alum slates of Sweden and Norway, which holds the same position there as in our own area.)

The second division or *upper* part of the Lower Lingula-flags of Salter (the typical Lingula-flags) are finely developed in North Wales, near Tremadoc and Ffestiniog, at Maentwrog, Borth, Marchllyn-Mawr, Llanberris, Carnedd Ffiliast, Dolgelly, and Trawsfynydd. *Cruziana semiplicata*, *Hymenocaris vermicauda*, *Olenus micrurus*, *Lingulella Davisii*, and *Microdiscus* are the leading types of this upper part of the lower series. Physically these are hard, grey, thick, sandy beds and flags.

The Upper Lingula-flags of Salter differ essentially from the Lower Division, consisting of dense black pyritous slates, or black slates with pyritous bands near the base, with a large fauna differing almost entirely from that of the Lower Lingula-flags; for out of 35 species occurring in the lower group, only 5 pass from the lower to the upper—namely *Agnostus princeps*, *Microdiscus punctatus*, *Lingulella Davisii*, *L. lepis*, and *Obolella sagittalis*, and this in the same district. At Tremadoc, Maentwrog, and west of Ffestiniog the beds are rich in fossils—*Olenus alatus*, *O. scarabæoides*, *Agnostus princeps*, *Conocoryphe depressa*, *C. invita*, *Orthis lenticularis*, and *Dictyonema* thickly crowding the beds.

It is well known that in 1851 Barrande visited England purposely to compare his fine series of fossils with our types, when he at once recognized the "Lingula-flags" of Sedgwick as the precise equivalent of his primordial stratum (Étage C). Barrande also carried out his comparison and correlation not only with the fauna of our country, but also between those of the European and American continents, with what success the literature and progress of geological science has shown.

The comparison of the Arenigs of Shropshire (Stiper stones) and Westmoreland (Skiddaw) will form an important feature for our consideration.

The close analyses of the Lower and Upper Lingula-flags must be taken separately. The faunas of the two differ remarkably; and only 8 species connect them—namely 5 species of Trilobita (*Asaphus princeps*, *A. trisectus*, *A. Salteri*, *Microdiscus punctatus*, and *Paradoxides Hicksii*) and 3 of Brachiopoda (*Lingulella Davisii*, *L. lepis*; and *Orthis sagittalis*). The Middle Lingula-flags of some authors contain also only 5 species:—1 Trilobite, *Conocoryphe bucephala*, Belt; 3 Brachiopoda, *Kutorgina cingulata*, Belt, *Lingula squamosa*, Holl, and *Lingulella Davisii*; with *Bellerophon cambrensis*, Belt. Two of the five species appear to be confined to this horizon, viz. *Lingula squamosa* and *Bellerophon cambrensis*. This fauna is too small to be of any value for our present purpose.

Plantæ.—No trace of any kind.

Protozoa.—The sponge *Protospongia fenestrata*, Salt., passes up from the Menevian and Harlech beds at St. David's to the Lower Lingula-flags. This species has the longest range of the four known forms; but none of the four ranges higher.

Hydrozoa.—No appearance; none occur before the Arenig rocks were deposited.

Actinozoa.—No traces of Cœlenterata in any form.

Echinodermata.—None occur in the Lingula-flags. The cystidean *Protocystites menevensis* is Menevian only; and the first Crinoid appears in the Lower Tremadoc of Ramsey Island.

Annelida.—Three genera and three species. The characteristic *Cruziana semiplicata*, Salt., hitherto has only been found in the Cambrian grits of the Bangor area, near Cwm Grainog and Carnedd-ffiliast, in North Wales (Lower Lingula-flags of the Survey).

Specimens of this *Cruziana* or an allied species have occurred below the Stiper stones in the Shelve country, W. of the Longmynds.

Scolicoderma tuberculata, from Pentre-felen quarry, near Wem Gate, Caernarvonshire, and *Helminthites* from the Maentwrog sandstones. None of these forms occurs out of the Lower Lingula-flags.

Crustacea.—This class is nearly equal in zoological value to what it is in the Menevian. 9 genera and 25 species have been described: 14 of the same species appeared before in the Menevian, and therefore occur in both formations; 6 species (*Agnostus princeps*, *A. trisectus*, *Anopolenus Salteri*, *Microdiscus punctatus*, *Paradoxides aurora*, and *P. Hicksii*) pass to the Upper Lingula-flags. Like the Menevian beds it is the home of *Agnostus*, 6 species of that genus occurring; but only 2 are peculiar or confined to the Lower Lingula-flags, viz. *Agnostus limbatus* and *A. nodosus*; besides these *Olenus cataractes*, Salt., *O. micrurus*, *O. gibbosus*, and *O. truncatus*? are also Trilobites confined to this horizon; the Phyllopod *Hymenocaris vermicauda* essentially characterizes the Lower Lingula-flags; so that, large as the Crustacean fauna appears (25 species), there are only 8 that are really Lower-Lingula species; the remaining 17 ally the Lower Lingula either with the two formations below or with the Upper Lingula and Tremadoc above. The 7 typical species are given above. The genus *Conocoryphe*, which is very largely represented in the Lower Cambrian rocks (by no less than 21 species), has no distinctive or peculiar form in the Lower Lingula-flags; 4 occur, but none are restricted. They are *Conocoryphe applanata*, *C. bucephala*, *C. humerosa*, and *C. variolaris*. 9 species of the genus *Conocoryphe* occur in the Upper Lingula-flags; and, as we shall see, this division possesses also more peculiar forms and a larger specific Crustacean fauna than the Lower Lingula-flags, but fewer genera. The species of *Conocoryphe* and other genera are as follows—*Agnostus obtusus*, *A. princeps*, *A. trisectus*, *A. Turneri*, *A. venulosus*, *Ampyx prænuntius*, *Anopolenus Salteri*, *Conocoryphe abdita*, *C. bufo*, *C. depressa*, *C. invita*, *C. malvernensis*, *C. longispina*, *C. Plantii*, *C. simplex*, *C. Williamsoni*, *Microdiscus punctatus*, *Olenus bisulcatus*, *O. flagellifer*, *O.* (*Sphærophthalmus*) *humilis*, *O. obesus*, *O. pauper*, *O. pecten*, *O.* (*Peltura*) *scarabœoides*, *O. serratus*, *O. spinulosus*, *Paradoxides aurora*, and *P. Hicksii*, also *Primitia solvensis*.

Bryozoa.—None have yet appeared.

Brachiopoda.—*Lingulella*, *Obolella*, and *Orthis* are the only 3 genera in the Lower Lingula-flags. The 5 species are *Lingulella Davisii* and *L. lepis* (both ranging to the Arenig), *L. ferruginea*, *Obolella maculata*, and *Orthis sagittalis*. The last named is also Tremadoc.

Lamellibranchiata.—None known below the Lower Tremadoc, where 3 new genera and 12 species suddenly appear; they will be noticed under the Lower Tremadoc beds.

Gasteropoda.—None occur beneath the Arenig rocks.

Pteropoda.—*Theca corrugata*, Salt., and *T. obtusa*, Salt., are the only 2 species that occur. The last named is confined to the Lower Lingula-flags.

Heteropoda.—None below the Middle Lingula-flags; and the only species occurring therein is *Bellerophon cambrensis*, Belt.

Cephalopoda.—None have yet appeared below the Upper Tremadoc, where the oldest forms known occur.

The fauna of the Lower Lingula-flags is expressed in the following Table; and it will be seen in the passage column that only 8 species pass to the Upper Lingula-flags. They are *Agnostus princeps*, *A. trisectus*, *Anopolenus Salteri*, *Microdiscus punctatus*, and *Paradoxides Hicksii*, *Lingullela Davisii*, *L. lepis*, and *Orthis sagittalis*. Only 2 species are believed to connect the Middle and Lower Lingula-flags—*Conocoryphe bucephala*, Belt, and *Lingulella Davisii*, M'Coy. Indeed the whole fauna of the middle division only amounts to 5 species—the two just named, and *Kutorgina cingulata*, Bill., *Lingula squamosa*, Holl, and *Bellerophon cambrensis*, Belt.

Nine entire classes are unrepresented in the Lower Lingula-flags, as shown in the Table.

Table III.—*Lower Lingula-flags.*

Pass up from Menevian.	Classes.	Genera.	Species.	Pass to Middle Lingula-flags.	Pass to Upper Lingula-flags.
	Plantæ.				
1/1	Protozoa	1	1		
	Hydrozoa.				
	Actinozoa.				
	Echinodermata.				
	Annelida	3	3		
8/14	Crustacea	9	25	1/1	4/5
	Bryozoa.				
3/3	Brachiopoda..............	3	5	1/1	3/3
	Lamellibranchiata.				
	Gasteropoda.				
1/1	Pteropoda................	1	2		
	Heteropoda.				
	Cephalopoda.				
13/19	....	17	36	2/2	7/8

Upper Lingula-flags.

Plantæ.—None known.

Protozoa.—None occur.

Hydrozoa.—*Dictyonema sociale* occurs abundantly in the grey and dark shales of Keys End Hill, Malvern, and in North Wales. Whether *Dictyonema* should be placed with the Hydrozoa or Bryozoa is still a doubtful question. Salter in 1857 separated this genus from Kjerulf's genus *Fenestella* and also from Hall's genus *Graptopora*.

Actinozoa.—None.

Echinodermata.—None.

Annelida.—2 genera, *Scolicoderma antiquissimum*, Salt., and *Serpulites fistula*, Holl. The Hollybush sandstone of the Malverns is characterized by the two Annelides above named; the Hollybush beds of the Wrekin also contain Annelide remains. *S. fistula* first appears in the Menevian beds. Whatever may be the age of the Hollybush sandstones, these two species occur in the Malvern area, at the base of the Upper Lingula-flags.

Crustacea.—No less than 30 species represent the following eight genera—*Agnostus* 5 species, *Ampyx* 1, *Anopolenus* 1, *Conocoryphe* 9, *Dikelocephalus* 2, *Microdiscus* 1, *Olenus* 9, *Paradoxides* 2*. 4 species, viz. *Agnostus princeps*, *Ampyx prænuntius*, *Conocoryphe depressa*, and *Olenus alatus*, pass from the Upper Lingula-flags to the Lower Tremadoc; and 20 species are confined to this horizon. Thus the Upper Lingula-flags through their Crustacea become of much importanc, and the few (4) that pass to the Tremadoc clearly show the stratigraphical value of the Lingula group and its distinctness. It may be worth stating that 4 species in the Upper Lingula-flags also occur in the Menevian; they are *Anopolenus Salteri*, *Microdiscus punctatus*, *Paradoxides aurora*, and *P. Hicksii*; only 2 species of the 4 that pass from the Upper Lingula-flags to the Tremadoc extend up into the Upper Tremadoc, namely *Agnostus princeps* and *Ampyx prænuntius*.

Bryozoa.—*Dictyonema sociale*, Salt., is the only Bryozoon known in the Upper Lingula-flags; it passes to the Lower Tremadoc, both in the North and South Welsh areas, at Tremadoc and St. David's; it is highly characteristic of the pale *Dictyonema*-shales that overlie the black shales in the valley of the White-leaved Oak at the southern end of the Malvern range†. These black and pale greenish Upper Lingula shales are about 500 feet thick, and contain a singular fauna of Crustacea and Brachiopoda. Prof. Phillips first noticed these shales and their fossil contents. The Crustacea are *Conocoryphe malvernensis*, Phill., *Olenus bisulcatus*, Phill., *O. humilis*, Phill., *O. spinulosus*, Phill., and *O. pauper*, Phill., *Sphærophthalmus pecten*, Salt., *Agnostus M'Coyi* ?, Salt., and *A. princeps*; the Brachiopoda are

* For list of the species see p. 80, last paragraph in the Lower Lingula-flag division.

† It is possible that Kjerulf's *Fenestella socialis* from Scandinavia may be our *Dictyonema*; Eichwald's *Gorgonia flabelliformis*, although much larger, is almost identical; Mr. Salter, however, established its generic distinctness.

Lingula pygmæa, Salt., *Obolella Salteri*, Holl, and *Spondylobolus*, sp.; many of these are peculiar to the Malvern area. Dr. Holl* in 1865 described the geological structure of the Malvern Hills and adjacent districts, placing these shales in the Upper Cambrian, the Hollybush sandstone being the base or lowest known sedimentary rock in the Malvern area. Whether *Dictyonema* should be classed with the Bryozoa or Hydrozoa is still a doubtful question.

Brachiopoda.—Only 5 genera and 8 species occur in the Upper Lingula beds—*Kutorgina cingulata*, *Lingulella Davisii*, *L. lepis*, *Lingula pygmæa*, *Obolella plicata*, *O. Salteri*, *O. sagittalis*, and *Orthis lenticularis*. 6 pass to the Tremadoc rocks—*Kutorgina cingulata*, *Lingulella Davisii*, *L. lepis*, *Obolella plicata*, *O. sagittalis*, *Orthis lenticularis*; only 2 species are really restricted to the Upper Lingula-flags, *Lingula pygmæa* and *Obolella Salteri*. No zoological value can therefore be attached to the Brachiopoda, as all the species but 2 occur both below and above the Upper Lingula-flags.

Lamellibranchiata.—None have as yet been detected.

Gasteropoda.—None known below the Arenig.

Pteropoda.—Of the 4 genera and 17 species that range from the Longmynd group of St. David's to the Upper Tremadoc no form has yet been discovered in the Upper Lingula-flags.

Heteropoda.—None have occurred, although 5 species range through the Lower Cambrian rocks. The so-called Middle Lingula-flags have yielded one species, *Bellerophon cambrensis*, Belt, which is the first known species on record.

Cephalopoda.—None of any type. No species occur below the Lower Tremadoc. The entire Cephalopod fauna of the Lower Cambrian rocks consists only of 1 genus and 2 species below the Arenig rocks, *Orthoceras precox*, Salt., and *O. sericeum*, Salt.; in the Upper Tremadoc these increase to 5 species.

Between the close of the deposition of the Menevian rocks and the close of the Upper Lingula-flags, 10 new genera appeared, viz. 3 Annelida, 1 Bryozoon, 4 Crustacea, and 2 Brachiopoda †, succeeded by 13 new species in the Tremadoc (Echinodermata 2 species, Crustacea 4, Lamellibranchiata 5, Cephalopoda 2 species). The known newly introduced genera in the Lingula-flags were, *Cruziana*, *Scolicoderma*, *Helminthites*, *Dictyonema*, *Parabolina*, *Dikelocephalus*, *Peltura*, *Hymenocaris*, *Lingula* and *Kutorgina*. Only 1 of these (*Lingula*) lived on after the deposition of those sediments we term Lingula-flags; this genus has appeared in almost every successive marine formation.

The Lower Lingula beds have yielded 17 genera and 36 species, and the Upper Lingula-flags 16 genera and 41 species, showing a generic loss or dying out of 7 genera in their upward succession; they appear to be *Protospongia*, *Cruziana*, *Helminthites*, *Anopolenus*, *Holocephalina*, *Hymenocaris*, and *Leperditia*.

* Quart. Journ. Geol. Soc. vol. xxi. 1865, pp. 72–102.

† *Cruziana* (*semiplicata*), *Scolicoderma* (*tuberculatum* and *antiquissimum*), *Helminthites* (sp.), *Dictyonema* (*sociale*), *Hymenocaris* (*vermicauda*), *Olenus* (*cataractes*), *Dikelocephalus* (*celticus* and *discoidalis*), also *Carausia* (*menevensis*), with *Lingula* and *Lingulella*.

The two accompanying small Tables (III. & IV.) relate to the distribution of the fauna of the Lower and Upper Lingula-flags, with the number of genera and species that pass to the Lower and Upper Tremadoc. Nine whole classes are unrepresented in each division ; only 2 classes, indeed, in either have real value, the Crustacea and Brachiopoda. I regard the Annelida as being wholly doubtful, so far as regards species: their presence and influence is manifest everywhere through the slates and flags of the lowest Palæozoic rocks ; but the fragmentary condition of the remains, as well as the uncertainty relative to their development and history, almost sets aside their numerical value as species in evidence.

In the Lower Lingula-flags the 25 species of Crustacea stand alone ; and, with the exception of *Hymenocaris vermicauda*, *Leperditia Hicksii*, and *Primitia solvensis*, all are Trilobita. Five species, all Trilobites, pass to the Upper Lingula-flags. The Upper Lingula-flag table is even more significant; for every one of the 30 species of Crustacea belongs to the group of Trilobita, and only 2 species pass to the Upper Tremadoc, *Agnostus princeps* and *Ampyx prænuntius*, and not one to the Arenig, from the Lingula-flags.

The left-hand column in all the tables shows the number of genera and species that pass up from the next underlying or older formation, the upper figure enumerating or expressing the number of genera, and the lower denoting the number of species in each class; the same plan is applied to the genera and species that pass up into the several formations as the case may be, and as expressed in the headings of the columns. The column headed classes and the two succeeding, marked genera and species, speak for themselves.

TABLE IV.—*Upper Lingula-flags.*

Pass up from Lower Lingula-flags.	Classes.	Genera.	Species.	Pass to Lower Tremadoc.	Pass to Upper Tremadoc.
	Plantæ.				
	Protozoa.				
	Hydrozoa.				
	Actinozoa.				
	Echinodermata.				
	Annelida	2	2		
4 5	Crustacea	8	30	4 4	2 2
	Bryozoa	1	1	1 1	
3 3	Brachiopoda	5	8	4 5	3 5
	Lamellibranchiata.				
	Gasteropoda.				
	Pteropoda.				
	Heteropoda.				
	Cephalopoda.				
7 8	....	16	41	9 10	5 7

Lower and Upper Tremadoc.

Prior to the year 1865 little or nothing was known of the Tremadoc rocks in the promontory of St. David's; but in North Wales they had been well studied by Sedgwick in 1847, and by Salter in 1857; and in 1866 Salter and Hicks catalogued all the species known up to that time*. Doubtless the Lower Tremadoc series are a continuation and natural close of the Upper Lingula-flags or Ffestiniog series (the Middle Cambrian of Sedgwick). The strict agreement, however, between the North- and South-Wales Tremadoc faunas was not thoroughly understood until Dr. Hicks in 1873 carefully described and correlated the palæontological relations that exist between the typical North- and South-Welsh areas. The researches of Dr. Hicks into the Tremadoc fauna of the mainland of St. David's and that of Ramsey Island made us then familiar with the physical relation and palæontological connexion between the two areas†. The prior and incomplete observations of Hicks and Salter in 1866 at Ramsey Island relative to the presence there of the Tremadoc rocks, Dr. Hicks in 1872 fully confirmed, being able to show their succession to, and conformable position with, the hard siliceous flaggy Lingula-flags. In this research he was assisted by three able and competent observers, Messrs. Homfray, Lightbody, and Hopkinson, the last-named naturalist subsequently contributing largely to the Arenig Hydrozoa from the same area. Dr. Hicks's labours further resulted in Mr. Davidson's learned paper upon the earliest British Brachiopoda, which contains a valuable table showing the distribution of all the known species of that class in these oldest British rocks (Harlech to Tremadoc‡).

Since the labours of Dr. Hicks in Wales, another important addition has been made to our knowledge of the distribution and fauna of the Lower Tremadoc rocks of the Wrekin area, through the careful research of C. Callaway, Esq., F.G.S. Mr. Callaway corrected errors made by the Survey, Sir R. Murchison, and Mr. Salter in the reading of the Harnage and Shineton beds in Shropshire. He described the Lower Palæozoic rocks that range from Wellington to Kenley (N.E. to S.W.). He paid no critical attention to rocks newer than the Caradoc; but he greatly changed the previous views as to the reading and structure of the county§. Mr. Callaway clearly showed that the Shineton Shales are of Lower-Tremadoc age, and that the "quartzite" rock that lies between the Shineton Shale and the Wrekin represents the Hollybush Sandstone of Malvern, which there underlies the black shales with *Oleni*, the equivalents of the Upper Lingula-flags. The determination by Mr. Callaway of the presence of a Tremadoc fauna in England is of high importance; and, singularly, most of the Shineton Tremadoc

* British Association Report, 1866.

† Quart. Journ. Geol. Soc. vol. xxix. p. 39 (1873).

‡ Geol. Mag. vol. v. (1868) pp. 303–315.

§ Callaway, Quart. Journ. Geol. Soc. vol. xxxiii. pp. 652–672.

species are new, and also many of the genera. The species assigned by the author as having most zoological value are *Conocoryphe monile*, Salter, *Olenus Salteri*, Call., *Olenus triarthrus*, Call., *Agnostus dux*, Call., *Lingulella Nicholsoni*, Call., *Obolella sabrinæ*, Call., *Asaphus* (*Asaphellus*) *Homfrayi*, Salt., *Asaphus* (*Platypeltis*) *Croftii*, Call.

Mr. Callaway also draws comparisons between the Shineton, Pedwardine, and Malvern series, showing their relations and affinities. All the species in the Shineton Shales are new except three, viz. *Conocoryphe monile*, Salt., *Asaphus* (*Asaphellus*) *Homfrayi*, and *Dictyonema sociale*; the fauna is therefore nearly unique. Mr. Callaway suggests that the Shineton Shales may be passage-beds between the Lingula-flags and the Lower Tremadoc: the presence of *Dictyonema sociale* strengthens this view; it is an Upper Lingula-flag species at Malvern, Pedwardine, and North Wales in many places, also a well-known Tremadoc form in the latter area. Mr. Callaway ably discusses the physical features of the Shineton area. He describes fourteen new species, and establishes two subgenera of Trilobites, *Asaphellus* and *Platypeltis*, and two genera, *Conophrys* and *Lichapyge*; he also determines and describes a remarkable Cystidean, possessing a slender crinoidal-like stem and simple calicular pinnulæ, which he names *Macrocystella Mariæ*. At present we know of no true Tremadoc rocks in the Stiperstones area; nor, indeed, are we sure of the presence of the true Lingula-flags in that district west of the Longmynds, unless the Stiperstones themselves represent them; but of this we have no organic proof, the series succeeding being Arenig or Skiddaw, formerly mapped and named Lower Llandeilo by Sir Roderick Murchison and the Survey. Mr. Callaway believes from recent research that the quartzites of the Stiperstones are of Arenig age, and therefore distinct from the quartzites of the Wrekin, deducing his opinion from the fact that when they are conglomeratic the pebbles in the Arenig quartzites are mainly quartz, while the included fragments of the Wrekin quartz rocks are felsitic. Again, Mr. Callaway believes that he has detected the Shineton Shales (Lower Tremadoc) at the base of the escarpment of the Stiperstones dipping under the Arenig series in the same direction as the rocks of that formation, *i. e.* W.N.W.

There is little or no specific palæontological affinity or community between the Tremadoc and Arenig groups in any known area in North or South Wales, although they are everywhere conformable. No Tremadoc rocks have yet been proved to occur above the Lingula-flags in the passes of Llanberris and Nant Francon or the adjoining regions, where the latter rocks are so finely and fully developed; neither is it yet quite certain that they occur in Anglesey. A few fossils lately found by Professor T. M'K. Hughes lead to a strong suspicion that the northern half of the island may yet yield a Tremadoc fauna. The singular Trilobite, *Neseuretus ramseyensis*, Hicks, found by Professor Hughes at Ty-hen near Llanerchymaedd, has not hitherto occurred in North Wales, but only on Ramsey Island and at Tremanhire (St. David's); and other remains occur with this form, furnishing strong evidence that the Tremadoc rocks extend as far N.W. in Wales as Anglesey: the above-mentioned species has not occurred in the classical Tremadoc area, either in the lower or the upper division of the group. The presence of the Arenig beds in Anglesey favours the belief that the Tremadoc may also occur in the island.

The Tremadoc slates, now so well known in the two classical Welsh localities, viz. Tremadoc in North, and St. David's in South Wales, are so rich in conspicuous forms and well-determined species that we readily recognize and place them in two distinct or separate horizons or zones. Their true position in North Wales, between the Lingula-flags below and the Arenig group above, was clearly shown and fixed by the distinguished Cambridge Professor in 1851. Their base was an easier line to trace than their passage above into what was then a group of rocks believed to be almost unfossiliferous. Small indeed was the fauna known to Sedgwick and Salter in 1843, when, at Tai-hirion, west of Arenig Mountain, they collected the two characteristic fossils *Ogygia Selwynii* and *Calymene parvifrons*. These two species formed the mental basis of Sedgwick's Arenig, and determined the top of his Tremadoc group till better worked out. Now the Tremadoc fauna of North Wales consists of 42 species, of South Wales 30, and of Shropshire (Shineton) 16. The Arenig group numbers 62 genera and 149 species; or 97 species occur at St. David's, 74 in the Skiddaw beds of Westmoreland, 36 in the Stiper-stones area, 34 in North Wales. These have nearly all been described since the far-seeing eye of Sedgwick determined the stratigraphical place of the groups on physical grounds. We owe the description of the species to Dr. Hicks, Mr. Salter, Professor M'Coy, and Messrs. Hopkinson, Lapworth, Nicholson, and Davidson. Guided by mineral or physical characters alone, the line of separation between the Lingula-flags and Lower Tremadoc would probably be drawn immediately above the hard grey arenaceous so-called Middle Lingula-flags, in the typical Tremadoc area, where *Lingulella Davisii* ceases to be an abundant and characteristic fossil; but zoological conditions forbid this; the "black slates" that succeed the "hard grey series," possess a recurrent generic fauna from the lower zones, including *Conocoryphe depressa*, *Dikelocephalus* ?, and *Agnostus princeps*, with *Orthis lenticularis*, the two latter in millions. The cliff of Ogof-ddu, near Criccieth, and the jutting promontory of Craig-ddu exhibit a complete section from the Lingula-flags to the Upper Tremadoc slates, the characteristic *Orthis lenticularis* marking by myriads the junction of the Middle Lingula-flags and the Upper Black pyritous slate. No Upper Lingula-flag section in Wales is more prolific in life: *Conocoryphe abdita*, Salt., and two other species, *Dikelocephalus celticus*, Salt., *D. discoidalis*, Salt., *Agnostus princeps*, and *Orthis lenticularis* dispel all doubts as to age or horizon; but the Tremadoc fossils do not occur at Ogof-ddu; the fossiliferous zones must be sought for in the sections at Penmorfa, Borthwood, Moel-y-gest, &c. near Portmadoc (places rich in characteristic species), and also across the estuary from Aber-ai, by Dudreath, to Cae-Iago, near Maentwrog.

These are the chief localities whence the history of the Tremadoc rocks of North Wales has been drawn and deduced, from which also their remarkable fauna has been disentombed, and that mainly through the instrumentality of Mr. David Homfray and Mr. Ash of Portmadoc, the late Mr. Salter, and the old collector for the Survey, Mr. Gibbs.

The careful and thorough examination of North and South Wales that has of late been made by so many able observers, has clearly shown the perfect sequence and agreement in stratigraphical succession between the whole of the groups ranging from the Harlech and Longmynd strata to the Llandeilo; this is complete for South Wales in the St.-David's promontory as one continuous and ascending section, with no break in continuity. It is not so clear or complete a sequence in North Wales, where the chief localities for the Tremadoc and Arenig groups are more widely separated, both formations being only developed in two counties in North Wales, viz. Merionethshire and Caernarvonshire—the Lower Tremadoc series chiefly at Penmorfa, Borthwood, and Llanerch in Caernarvonshire, and in Merionethshire at Cae Iago near Maentwrog and at Tyn-y-llan. The Upper Tremadoc rocks, on the contrary, are best developed in Merionethshire at Tuhunt-y-bwlch, Penclogwyn, and Garth, whilst Moel-y-gest is the only locality in Caernarvonshire where they occur. The Arenigs, which also occur only in the same counties, I shall have occasion to refer to at considerable length when speaking of the distribution of the species.

The discovery near St. David's, by Hicks and Salter, of Tremadoc slates equivalent to those of North Wales threw new light upon the history of that remarkable promontory. Not only are these slates the same as those of Merioneth and Caernarvonshire, but a large number of additional species of much interest have been added to the whole fauna. In 1866 * Messrs. Hicks and Salter published the results of their researches at St. David's, giving a list of the species discovered by them. Since then Dr. Hicks has reaped a large harvest of new forms from these rocks, thus adding to the history and palæontology of that area—no less than thirty species having occurred to him. These were obtained from three distinct localities—the first on the north-eastern coast of Ramsey Island; the second at the northern extremity of Whitesand Bay, and extending 4 miles in a north-easterly direction beneath the Arenig rocks; the third at Tremanhire, an extensive area or tract 5 miles east of St. David's, thus showing extensive geographical distribution. The Ramsey-Island section is stratigraphically complete, having for its conformable base the Lingula-flags full of *Lingulella Davisii*; and upon the intervening Tremadoc rocks, here 1000 feet thick, succeed the Arenigs, thus here, as at Whitesand Bay, affording clear proof of the intercalated position of the Tremadoc group. In North Wales no Arenig rocks are known to rest directly upon the Tremadoc anywhere. Dr. Hicks obtained in all 29 species from the Ramsey-Island section, 24 of which were new; and 15 occurred at Tremanhire, inland, east of St. David's.

* Brit. Assoc. Report, 1866, p. 182.

The Tremadoc rocks of Whitesand Bay also rest conformably upon the Lingula-flags, and underlie the Arenigs, as at Ramsey Island; they strike north-east for 4 miles towards Abereiddy Bay. The third exposure, at Tremanhire, shows the same stratigraphical relations and succession, and has yielded fifteen out of the 30 new species described by Hicks as occurring at Ramsey Island. This patch is now an isolated inlier surrounded by Lingula-flags and Menevian beds, and with a large area of Longmynd rocks to the west. The Pre-Cambrian ridge and Longmynd series now divide or separate the two Tremadoc areas, which must have been once continuous. Dr. Hicks believes that the conditions under which these rocks at St. David's were deposited were intermediate between those of the shoal and shallow water in which the Lingula-flags were deposited, and those of the deeper sea from which the finer muddy deposits of the Arenig slates were thrown down, and that this was probably one of the causes of the appearance in them of so varied a group of organisms.

There is some difficulty in comparing the Tremadoc rocks of North with those of South Wales. At St. David's they are so intimately connected with the underlying Lingula-flags and overlying Arenig series that the boundary-line is almost arbitrary. Palæontologically they appear to be on the same horizon as the Lower Tremadoc series of North Wales, the chief trilobite *Niobe Homfrayi* with *Lingulella Davisii* and *L. lepis* connecting them. Yet the mass of the faunas are entirely distinct, for out of the 42 North-Wales and 30 South-Wales forms only the 3 above named are common to both.

Thus out of the 4 North-Wales and 7 South-Wales Trilobita only 1, *Niobe Homfrayi*, connects the two areas. Of the 4 genera and 9 species of Brachiopoda occurring in both areas only 2 species connect them, viz. *Lingulella Davisii* and *L. lepis*; and more remarkable still is the occurrence in Ramsey Island of the earliest known Lamellibranchs in Britain, if not in Europe. The Lower Tremadoc beds in that island have yielded 5 genera and 12 species, the first representatives known of that order; 6 of the same species occur inland at Tremanhire. Three of these genera belong to the Arcidæ, and one probably to the Anatinidæ; prior to this discovery *Redonia*, *Ribieria*, and a species of *Palæarca* were the oldest forms known, and were obtained from the Arenig beds at Lord's Hill, Shelve. The last-named genus has been extracted from Lower Silurian rocks in Spain, Bohemia, France, and Devonshire. These bivalves are also associated with the earliest known Crinoid and Starfish, *Dendrocrinus cambrensis* and *Palæasterina ramseyensis*. Still more significant zoologically is the presence of a new genus with four species of Trilobita, which Dr. Hicks has named *Neseuretus*. This large and singular genus seems to have affinity with *Dikelocephalus* through its pygidium, with *Calymene* and *Homalonotus* through the thoracic segments, and with the Conocephalidæ through the glabella. The four species and one variety are all confined to the Lower Tremadoc rocks of Ramsey Island and Tremanhire on the St.-David's promontory. None had occurred in

North Wales until Prof. Hughes discovered portions of one in Anglesey. If any other Trilobite were required to establish palæontological relationship between the Tremadoc rocks of North and South Wales it would be Angelin's genus *Niobe*; and Dr. Hicks has obtained, both from Ramsey Island and Tremanhire, a new and splendid species (*Niobe menapiensis*), greatly exceeding in size the characteristic *Niobe Homfrayi* from Penmorfa and Tremadoc. *Niobe* is not known out of the Tremadoc group. The South-Wales beds do not possess so numerous an assemblage of pelagic Mollusca as those of North Wales: 9 species of Pteropoda (*Theca Davisii, T. opercula*, Lower Tremadoc only, *T. arata, T. bijugosa, T. cuspidata*, Lower and Upper, and *T. alata, T. simplex*, and *T. trilineata*, with *Conularia Homfrayi*) are Upper Tremadoc; and 5 Heteropoda (*Bellerophon arfonensis, B multistriatus, B. ramseyensis, B. solvensis*, and *B. shinetonensis*) range through the Tremadocs; but *Theca Davisii, Bellerophon ramseyensis*, Hicks, and *B. solvensis*, Hicks, are South-Wales species, the mass occurring in the typical Tremadoc area in North Wales. Associated with *Niobe menapiensis* and the *Neseureti* no less than 19 species occur, including the 12 Lamellibranchs and 5 Brachiopoda, viz. *Lingulella Davisii, Lingula petalon, Obolella plicata, Orthis Carausii*, and *O. menapiæ*, 29 of the 31 being described by Hicks. Dr. Hicks believes that the lower portion of the St.-David's Tremadoc rocks and the upper black slates of the Lingula-flags of North Wales were deposited contemporaneously. This may well be, looking at the remarkable difference existing in the faunas of the two areas, so few species being common to or uniting the two groups, and difference of depth at the time of deposition. Again, the absence of the fine black slates in the Upper Lingula-flags of St. David's, so characteristic of the North-Wales and the Malvern beds, may be due to depth, shallow in one region and deep in the other.

The Tremadoc series is divided into three groups by Dr. Hicks, the lowest at St. David's consisting of grey, fissile, or flaggy sandstones. Exposed at Ramsey Island, Tremanhire, and Llanveran, a peculiar assemblage of fossils occurs in this area, new and different from that of North Wales:—*Davidia, Glyptarca*, and *Palæarca*, being the earliest bivalves known; the earliest Crinoid, *Dendrocrinus* (unless Mr. Callaway's genus *Macrostella* from the Shineton area should be earlier in time); and the first known Asteroid, *Palæasterina ramseyensis*, Hicks. The Middle Tremadoc of Hicks is equivalent to the passage-beds between the Lower and Upper series of Salter, containing *Cheirurus Frederici, Conocoryphe verisimilis, C. vexata*, and *Asaphus Homfrayi*,—the upper member, consisting of iron-stained slates and flags at Penclogwyn, Garth, Dudreath Tuhwnt-yr-bwlch, &c., in the Portmadoc area being characterized by *Angelina Sedgwickii, Lingulocaris lingulæcomes*, and *Conularia Homfrayi*. The distinctness of the Tremadoc from the Lingula-flags below is in all areas the same; only 8 species out of 65 known forms in the former pass up to the Tremadoc, which possesses a fauna of 84 species; these are *Agnostus princeps, Ampyx prænuntius, Conocoryphe depressa, Lingulella Davisii, L. lepis, Orthis lenticularis, Obolella* *sagittalis*, and *Dictyonema sociale*. 42 species are known in North Wales, and 30 in South Wales; yet, as before stated, only 3 species are common to both districts—*Niobe Homfrayi*, *Lingulella Davisii*, and *L. lepis*.

It must be observed that no species of true Graptolite is known in the Tremadoc rocks, none being really known below the Arenig in Britain, Europe, or America. Doubtless the whole Arenig series is more closely allied to the succeeding and overlying Llandeilo than to the underlying Tremadoc; it is certainly so as exhibited in the South-Wales promontory, where both groups are typically developed and succeed each other in one continuous and conformable section; yet there is perhaps no greater change or palæontological break between any two conformable British groups than between the Tremadoc and Arenig, the rich Hydrozoal fauna coming in at the close of the former and commencement of the latter. The change in the physical conditions of the sea and sea-bed at the close of the Tremadoc period was favourable to the development of this division of the Cœlenterata.

The most characteristic of all the fossils of the Lower Tremadoc are *Niobe Homfrayi*, *N. menapiensis*, *Psilocephalus innotatus*, with *Angelina Sedgwickii* and *Asaphus affinis* in the Upper Tremadoc; these five species are met with wherever the Tremadoc rocks are well seen. *Agnostus princeps*, so abundant in the Upper Lingula-flags of North Wales, is not known in the St.-David's Tremadoc sections, and is of the rarest occurrence in the North-Welsh classical localities; with *Agnostus* the characteristic *Lingulella* (*L. Davisii*) dwindles away, and seems to be replaced by the small but equally gregarious *L. lepis*.

The true Upper Tremadoc series is characterized by many new species. *Niobe Homfrayi*, *Psilocephalus innotatus*, and *P. inflatus* no longer exist as species, but are replaced by *Asaphus Homfrayi* and *Angelina Sedgwicki*; *Cheirurus Frederici* at Garth, Llanerch, Penclogwyn, Portmadoc, &c., ranges from the top of the Lower, through the passage-beds, and all through the Upper Tremadoc into the Arenig. *Olenus impar* adds another to the characteristic species of the Upper Tremadoc; and *Cyrtoceras præcox*, which occurs at Llanerch, *is the earliest known Cephalopod in the British rocks.* The first *Orthoceras* (*O. sericeum*) known* also occurs in the passage-beds at Garth and Tuhwnt-yr-bwlch.

It is clear that there is no stratigraphical or palæontological break between the Lingula-flags and the Tremadoc: both areas prove the former by direct evidence; and 9 species connect them palæontologically, viz. *Dictyonema sociale*, Salt., *Agnostus princeps*, Salt., *Ampyx prænuntius*, Salt., *Conocoryphe depressa*, Salt., ?*Olenus impar*, Salt., *Lingulellu Davisii*, M'Coy, *L. lepis*, Salt., *Obolella sagittalis*?, Salt., *Orthis lenticularis*, Wahl. Three of these same species also connect the Tremadoc and Arenig: they are *Lingulella Davisii*, *L. lepis*, and *Orthis lenticularis*. All palæontological evidence goes to prove "that the Tremadoc rocks of the St.-David's area are closely allied to, if not identical with, the lower portion of the

* Originally in the cabinet of Mr. D. Homfray, of Portmadoc.

Tremadoc rocks of North Wales." Mr. Homfray, of Portmadoc, than whom no one has had greater experience or more carefully studied the Tremadoc rocks in their original localities, finds no difficulty in recognizing and correlating the rocks and fossils of the two districts, affirming the St.-David's beds to be the equivalents of the lower portion of the series in the Portmadoc region. Mr. Homfray is also of opinion that the Upper Tremadoc rocks are represented at St. David's by part of the Arenigs, which contain several Upper-Tremadoc fossils, in addition to the rich fauna of Graptolites (42 species) now known to occur through the entire Arenig series. The whole Tremadoc fauna consists of 33 genera and 86 species, and no Hydrozoa; the Arenig includes 62 genera and 149 species, with 42 species of Hydrozoa; the succeeding Llandeilo has 230 species, 90 of which are also Hydrozoa; yet in each formation the Graptolites appear mostly to be of distinct species. They also play an important part in the faunas of the Llandeilo, Caradoc, and Llandovery rocks of Scotland.

Table VII. (p. 100) is a complete numerical analysis of the fossils in the Lower Cambrian rocks, from the Harlech and Longmynd to the close of the Upper Tremadoc, in which it will be seen that the twelve classes (and Plantæ?) are represented by 61 genera and 182 species, as the known commencement of life in the British area. They are as follows:—

The Longmynd group	contains	18	genera and	33	known	species.
The Menevian	,,	24	,,	51	,,	,,
The Lower Lingula-flags	,,	19	,,	38	,,	,,
The Upper ,, ,,	,,	12	,,	40	,,	,,
The Lower Tremadoc	,,	26	,,	55	,,	,,
The Upper ,,	,,	21	,,	34	,,	,,

11 genera and 16 species pass to the Arenig, this small number clearly determining the individuality of the Lower Cambrian fauna. It is only through the 6 species of Crustacea out of 103, and the 6 Brachiopoda out of 20, that the passage-forms are thus numerous. The remaining 3 species are pelagic, 1 Pteropod, 1 Heteropod, and 1 Cephalopod.

Lower Tremadoc.

Plantæ.—None. Protozoa.—None known.

Hydrozoa.— Dr. Callaway discovered in the Shineton Tremadoc rocks two species previously unknown. One belongs to the genus *Clonograptus* of Hall; the other is the *Bryograptus Callavei* of Lapworth, both belonging to the family Dichograptidæ. These are the oldest Rhabdophora known.

Actinozoa.—None, so far as we know, below the Llandeilo rocks.

Echinodermata.—*Dendrocrinus cambrensis*, Hicks, and *Palæasterina ramseyensis*, Hicks, are both from the Lower Tremadoc beds of Ramsey Island, St. David's; they are the first known species of the orders Crinoidea and Asteroidea; and they stand with numerous other discoveries as a testimony of the value of the researches of Dr. Hicks in these early Cambrian rocks, to which Palæozoic palæontology owes so much.

Annelida.—None, either in the rocks of South or North Wales.

CRUSTACEA.—Only 2 new genera appear with the coming-in of the Lower Tremadoc (*Psilocephalus* and *Neseuretus*); but the whole Crustacean fauna comprises 13 genera and 24 species, of which 10 genera and 19 species especially characterize the Lower Tremadoc. They are so essential to a right understanding of the Lower Tremadoc rocks and their entire distinctness from the Upper Lingula-flags that I enumerate them:—*Agnostus Barlowii*, Belt; *A. dux*, Call.; *Conophrys salopiensis*, Call.; *Asaphus Croftii*, Call.; *Dionide atra*, Salt.; *Lichapyge cuspidata*, Call.; *Neseuretus* (5 species, all by Dr. Hicks); *Niobe Homfrayi*, Salt.; *N. menapiensis*, Hicks; *N. solvensis*, Hicks; *Conocoryphe verisimilis*, Salt.; *Olenus triarthrus*, Call.; *O. Salteri*, Call.; *Psilocephalus inflatus*, Hicks; and *P. innotatus*, Salt. None of the above species occurs below or above the Lower Tremadoc horizon. The remaining five occur also in the Upper Lingula-flags, and unite the two formations. The chief species named occur at Penmorfa, Borthwood, and Llanerch in Caernarvonshire, and Dudreath and Tyn-y-llan in Merioneth; and the same species occur in the St.-David's promontory at Whitesand Bay, &c. Nowhere do the species above mentioned transgress the lower beds; the Lower and Upper Tremadoc are connected only by *Agnostus princeps*, *Ampyx prænuntius*, and *Ogygia scutatrix*. Nothing that I could adduce would be stronger evidence of the value of the Lower Tremadoc as a well-defined zoological group: it contains more genera than any other division of the Lower Cambrian stages; and the species are essentially characteristic.

BRYOZOA.—*Dictyonema sociale*, Salt., as in the Upper Lingula-flags. This genus occurs near Tremadoc in the passage-beds.

BRACHIOPODA.—The Lower Tremadoc Brachiopoda are *Kutorgina cingulata*, *Lingula petalon*, *Lingulella Nicholsoni*, *L. lepis*, *Obolella Beltii*, *O. sabrinæ*, *O. plicata*, and *O. sagittalis*. *Orthis carausii*, *O. lenticularis*, and *O. menapiæ*. 4 of these 5 genera and 6 of the 11 species pass to the Upper Tremadoc. They are *Lingula petalon*, *Lingulella lepis*, *Obolella Beltii*, *O. plicata*, *Orthis carausii*, and *O. lenticularis*. 4 genera and 5 species appear from the Upper Lingula flags, so that the true Lower Tremadoc species are few, and only 2 species are peculiar, viz. *Lingulella Nicholsoni* and *Obolella sabrinæ*.

LAMELLIBRANCHIATA.—The first appearance of this class, or the earliest known in the British rocks. Dr. Hicks, through his researches upon the Tremadoc rocks of Ramsey Island, has obtained these first evidences of Pelecypod or bivalve molluscan life. He refers them (and, I think, rightly) to 5 genera and 12 species—*Davidia* (2), *Glyptarca* (2), *Modiolopsis* (4), *Palæarca* (2), and *Ctenodonta* (2); none of the species is known out of or above the Lower Tremadoc.

GASTEROPODA.—None known below the Arenig rocks.

PTEROPODA.—The genus *Theca* is represented by 5 species in the Lower Tremadoc, viz. *Theca ovata*, Salt., *T. bijugosa*, Salt., *T. cuspidata*, *T. Davisii*, and *T. (Cleidotheca) operculata*. The 3 first named pass to the Upper Tremadoc. *T. Davisii* is the only species in the Tremadoc rocks of St. David's. The remaining 4 are North-Welsh Tremadoc species.

HETEROPODA.—*Bellerophon ramseyensis*, Hicks, *B. solvensis*, Hicks, and *B. shinetonensis*, Call.; the former both Menapian forms, characterizing the Tremanhire or Solva and Ramsey-Island beds, St. David's.

CEPHALOPODA.—None below the Upper Tremadoc.

The analytical Table No. V. shows that 28 genera and 58 species occur in the Lower Tremadoc beds of North and South Wales. Three classes only are of numerical importance:—the Crustacea with 13 genera and 24 species; the Brachiopoda, with 5 genera and 11 species; the Lamellibranchiata, 5 genera and 12 species. These 3 groups constitute the mass of the known genera and species, or 23 out of 29 genera and 47 out of 59 species.

TABLE V.—*Lower Tremadoc.*

From Upper Lingula-flags.	Classes.	Genera.	Species.	Pass to Upper Tremadoc.
	Plantæ.			
	Protozoa.			
	Hydrozoa.			
	Actinozoa.			
	Echinodermata	2	2	
	Annelida..			
4/4	Crustacea	13	24	4/4
1/1	Bryozoa.	1	1	
4/5	Brachiopoda	5	11	4/6
	Lamellibranchiata...	5	12	
	Gasteropoda.			
	Pteropoda	1	5	1/3
	Heteropoda	1	3	
	Cephalopoda.			
8/9	....	28	58	9/13

UPPER TREMADOC.

PLANTÆ.—None.

PROTOZOA.—None.

HYDROZOA.—None.

ECHINODERMATA.—None.

ANNELIDA.—Tracks only.

CRUSTACEA.—11 genera and 15 species constitute the Crustacean fauna of the Upper Tremadoc; 12 of the 15 species are Trilobita; the remaining 3, *Ceratiocaris* (2 species) and *Lingulocaris*, are Phyllopoda, and the first of this order known in the British rocks. *Asaphus affinis*, M'Coy, *A. Homfrayi*, Salt., *Cheirurus Frederici*, Salt., *Dionide atra*, Salt., *Ogygia scutatrix*, Salt., and *O. Selwynii*, Salt., pass to the Arenig, and, with 6 Brachiopoda and 3 Pteropoda, constitute the 13 uniting forms out of a total of 182 species in the Lower Cambrian rocks and 150 in the Arenig.

The following 5 Crustacea only are confined to the Upper Tremadoc —*Angelina Sedgwickii*, *Conocoryphe olenoides*, *Olenus impar*, *Ceratioris latus*, and *Lingulocaris lingulocomes*. I am careful to name these as the first zoological or palæontological break between the Lower and Upper Cambrian, or the Cambrian and Silurian, takes place here, and that without any stratigraphical or physical unconformity. No greater faunal change is known to take place through the whole of the Palæozoic rocks than at the close of the Tremadoc or Lower Cambrian.

Bryozoa.—None known.

Brachiopoda.—Only 4 genera and 7 species occur; and 6 of these pass to the Arenig. They have therefore no stratigraphical value. *Obolella Belti* is the single remaining or restricted form.

Lamellibranchiata.—None yet known.

Gasteropoda.—None have yet occurred below the Arenig.

Pteropoda.—*Conularia* and *Theca*—the first with 1 species, *C. Homfrayi*, which is also Arenig; the latter contains 6, one of which (*Theca simplex*) also passes to the Arenig.

Heteropoda.—*Bellerophon arfonensis*, Salt., and *B. multistriatus*, Salt., are the only Upper-Tremadoc species. The last-named species is Arenig also.

Cephalopoda.—*Cyrtoceras præcox*, Salt., and *Orthoceras sericeum*, Salt.; the last also passes to the Arenig; they are the first Cephalopods known; and it is doubtful if *Cyrtoceras præcox* is not Lower Tremadoc also. The rich locality Garth yields *O. sericeum* from the upper part of the Upper Tremadoc. The Arenig of Llanvirn at St. David's has yielded the same; it is therefore both a North- and South-Wales species, from the Tremadoc in one area, the Arenig in the other.

Table VI.—*Upper Tremadoc.*

From Lower Tremadoc.	Classes.	Genera.	Species.	Pass to Arenig.
	Plantæ.			
	Protozoa.			
	Hydrozoa.			
	Actinozoa.			
	Echinodermata.			
	Annelida.			
4/4	Crustacea	11	15	4/6
	Bryozoa.			
4/6	Brachiopoda	4	7	3/6
	Lamellibranchiata.			
	Gasteropoda.			
1/3	Pteropoda	2	7	2/2
	Heteropoda	1	2	1/1
	Cephalopoda	2	2	1/1
9/13	....	20	33	11/16

Description of the first six Tables.

I have in this oldest Cambrian series (from the Longmynd rocks to the Upper Tremadoc) given an analytical table for each of the 6 formations or groups of strata. They cannot be otherwise thoroughly comprehended, taken as a whole, without wearisome description, owing to the non-representation of some classes, and the unequal representation and distribution of others. Nevertheless I have constructed Table No. VII. for the whole, to show the unequal distribution, the Table delineates every thing, its accuracy being tested through the six smaller tables (Nos. I. to VI.), wherein are given the analyses of all the groups separately. More than this, these six small tables enable the student to see immediately the numerical value of each division, and the number of species that pass up or live on to the succeeding period or formation. Again, there is much difficulty in following some authors through the many subdivisions and local names adopted by them for the strata between the Longmynd group and the close of the Upper Tremadoc. The succeeding Arenig, in which some of the classes are largely represented, while the formation is widely diffused geographically, enables me to show the distribution in one Table (No. VIII.); the same is also done for every succeeding epoch.

The Longmynd and Harlech Groups.—Table I. enumerates the fauna of the Longmynd and Harlech beds only, chiefly those of St. David's, and the first traces of life in the British Islands. In this Table 8 if not 9 of the 14 classes have no representatives, no species of them having as yet occurred; and, with the exception of the Crustacea, the remaining 5 classes are but feebly illustrated. This Table, however, at once lays bare the fact that we are not tabulating the commencement of life even in our own area; both the rock masses and the fossils that do occur, notably the great *Paradoxides*, bid us search still deeper in time for their ancestors as well as those of the pelagic Mollusca, as also of the Brachiopoda (*Lingulæ*, *Obolellæ*, and others). All these and the Lyssakine hexactinellid sponges had their progenitors, which we have yet to determine. I doubt not that much light will yet be thrown upon them through patient research.

This first Table shows that the Longmynd and Harlech rocks are known at the present time to possess 18 genera and 33 species—the commencement of life, so far as we know. The Crustacea are the most abundant class; 7 genera and 14 species occur: these earliest rocks of St. David's yield *Agnostus cambrensis*, Hicks, *Conocoryphe bufo*, Hicks, *C. Lyellii*, Hicks, *C. solvensis*, Hicks, *Microdiscus sculptus*, Hicks, *Paradoxides aurora*, Salt., *P. Hicksii*, Salt., *P. Harknessii*, Hicks, *P. solvensis*, Hicks, MS., *Plutonia Sedgwickii*, Hicks, and the Longmynd form *Palæopyge Ramsayii*, Salt.; the Ostracoda are *Leperditia ferruginea*, *L. cambrensis*, Hicks, and *L. primæva*. 4 of the above species pass to the Menevian—*Agnostus cambrensis*, *Conocoryphe bufo*, *Paradoxides aurora*, and *P. Hicksii*. Out of the 6 species of Brachiopoda, 4 also pass to the Menevian—

Lingulella ferruginea, Salt., and var. *ovalis*, Hicks, *Orthis sagittalis*, and *Discina pileolus*. The special or restricted forms are only 2—*Discina caerfaiensis*, Hicks, MS., and *Lingulella primæva*, Hicks. The Plantæ? and Protozoa are mentioned under those heads in the analysis. The table shows that 8 out of the 14 classes are not represented in the Harlech group. That they will remain so under renewed search and scrutiny I much doubt. Each year adds some new form to these once believed to be unfossiliferous strata. North Wales has yet to yield up from these rocks a fauna equal to that of South Wales.

Menevian.—Table II. gives us all that is known of the Menevian fauna and its relation to the Harlech series and the succeeding Lower Lingula-flags, of which, indeed, it is but the base; for out of the 24 genera and 51 species in the Menevian, 13 of the former and 19 of the latter are common to the two. Of the Crustacea 8 of the 12 known genera, including 14 species, are the same—viz. *Agnostus* (*A. Davidis*, *A. scutalis*), *Anopolenus* (*A. Henrici*, *A. Salteri*), *Conocoryphe* (*C. applanata*, *C. humerosa*, *C. variolaris*), *Holocephalina* (*H. primordialis*), *Leperditia* (*L. Hicksii*), *Primitia* (*P. solvensis*), *Microdiscus* (*M. punctatus*), *Paradoxides* (*P. aurora*, *P. Davidis*, and *P. Hicksii*); and 3 of the 4 genera of Brachiopoda, *Lingulella* (*L. ferruginea*), *Obolella* (*O. maculata*), and *Orthis* (*O. sagittalis*). Of the 6 species of Pteropoda, only 1 is common to the 2 groups, namely *Theca corrugata*. The Menevian is united to the Harlech and Longmynd rocks through 8 genera and 12 species. The Crustacea by 3 genera with 4 species, viz. *Agnostus* (*cambrensis*), *Conocoryphe* (*bufo*), *Paradoxides* (*P. aurora* and *P. Hicksii*); and the Brachiopoda the same, *Discina* (*pileolus*), *Lingulella* (*ferruginea* and var. *ovalis*), and *Orthis* (*sagittalis*). The Lyssakine sponge (*Protospongia*) and *Theca penultima* complete the alliance. 8 of the 14 classes are not represented. The first Cystidean, *Protocystites menevensis*, Hicks, occurs in the Menevians of St. David's. 11 new genera (not known in the Harlech group) first occurred in the Menevian sea; 6 are Crustacea, 2 Pteropoda, 1 Cystidean, 1 Annelide, and 1 Brachiopod? No species pass from the Menevian to the Middle or Upper Lingula-flags.

Lower Lingula-flags.—Table III. But for the Crustacea, the Lower Lingula-flags would have no value as a subformation; they are but the upper, continuous development of the Menevian. Only one genus of Crustacea, the Phyllopod *Hymenocaris*, is new to the Lower Lingula-flags; the remaining 8 are also Menevian; and 14 of the 25 crustacean species also occur in the Menevian below. Still further, of the 17 known Lower Lingula-flag genera, 13 are Menevian; and this close association is more marked still from the fact that only 2 species pass to the Middle and 8 to the Upper Lingula-beds; so that there is a greater difference between the Lower and Upper Lingula-beds themselves than between the former and the underlying Menevian. The Upper Lingula-flags, through their Crustacea, 8 genera and 30 species, stand alone.

Upper Lingula-flags.—Table IV. Out of a community of 17 genera and 36 species in the Lower, and 16 genera and 41 species in the Upper Lingula-flags, only 8 genera and 8 species unite the two groups: they are 5 Trilobita and 3 Brachiopoda—namely *Anopolenus Salteri*, Hicks, *Microdiscus punctatus*, Salt., *Agnostus princeps*, Salt., *Paradoxides Hicksii*, Salt., *P. aurora*, Salt., *Lingulella Davisii*, *L. lepis*, and *Orthis sagittalis*. Only 4 classes are represented in the Upper Lingula-flags, the Annelida, Crustacea, Bryozoa, and Brachiopoda. The remaining 10 have no representative whatever. 16 genera and 41 species occur in the Upper Lingula-beds; 8 genera and 30 species are Crustacea, and 5 genera and 8 species Brachiopoda; there are 2 Annelida, and 1 Bryozoon, *Dictyonema*. 9 genera and 10 species pass to the Lower Tremadoc.

Lower Tremadoc.—Table V. The Lower Tremadoc fauna numerically consists of 28 genera and 58 species; and the fauna is compact and characteristic. Only 8 genera and 9 species appear from the Upper Lingula-flags below: 4 of them are Crustacea; and 5 are Brachiopoda, and, with *Dictyonema*, complete the incoming species. The one remarkable feature in the group is the presence and first appearance of 5 genera and 12 species of Lamellibranchiata. Dr. Hicks discovered them in the Upper Tremadoc beds on Ramsey Island. They mark an epoch in the history of the class. *Davidia* and *Glyptarca* are new genera, *Modiolopsis*, *Palæarca*, and *Ctenodonta* receive Mr. Hicks's 8 other species. Until this class is found in lower beds, these 12 species identify the Lower Tremadoc of Ramsey Island as an important horizon in time and space. Only 4 of the 13 genera and 4 of the 24 species of Crustacea pass to the Upper Tremadoc; they are *Agnostus princeps*, *Ampyx prænuntius*, *Olenus alatus*, and *Dikelocephalus furca*; and 4 genera and 6 of the 12 species of Brachiopoda also connect the Upper with the Lower Tremadoc; they comprise the following—*Lingula petalon*, *Lingulella lepis*, *Obolella Belti*, *O. plicata*, *Orthis Carausii*, and *O. lenticularis*. These and *Theca ovata*, *T. bijugosa*, and *T. cuspidata*, in all 9 genera and 13 species, constitute the transgressing fauna.

Upper Tremadoc.—Table VI. Nine whole classes are wanting in this uppermost division of the Lower Cambrian rocks. Only 20 genera and 33 species compose the fauna of the Upper Tremadoc. We have seen that 9 genera and 13 species pass from the Lower Tremadoc, thus leaving only 11 genera and 20 species as truly belonging to the Upper Tremadoc. More than 50 per cent. of the species pass to the Arenig, or 11 genera and 16 species. These few species little affect the question of the palæontological break that takes place here; for 42 new genera and 133 new species make their appearance in the succeeding Arenig, through some physical changes accompanying the zoological, which we have not yet been able to satisfactorily discover. Unconformity between this group and the Arenig is not known in the typical areas of South and North Wales; but at no time in the history of the lowest Palæozoic rocks has apparent extinction on the one hand, and migration from some unknown area in the other, taken place so markedly. We have yet to learn or trace whence came for the first time the 17 genera of Hydrozoa, the 17 genera of Crustacea, 5 Annelida, 3 genera of Brachiopoda, and 5 of other Mollusca, &c., all presenting a different facies, or an aspect having little affinity with the previously existing fauna. The advent of the 17 genera and 42 species of Hydrozoa and the 35 species of Crustacea, all new forms and widely spread, has still to be explained. The 13 species connecting the Upper Tremadoc with the Arenig belong chiefly to the Crustacea and Brachiopoda, these two classes yielding 13 out of the 16 species. The 6 Crustacea are *Asaphus affinis*, M'Coy, *A. Homfrayi*, Salt., *Cheirurus Frederici*, Salt., *Dionide atra*, Salt., *Ogygia scutatrix*, Salt., and *O. Selwynii*, Salt.; and the Brachiopoda, *Lingula petalon*, Hicks, *Lingulella Davisii*, M'Coy, *L. lepis*, Salt., *Obolella plicata*, Hicks, *Orthis Carausii* (Hicks), and *O. lenticularis*. With these are *Theca simplex*, Salt., *Conularia Homfrayi*, Salt., and *Bellerophon multistriatus*, Salt.

The Table numbered VII. embraces or shows the numerical value and stratigraphical distribution of the species through all the Lower Cambrian divisions, or from the Longmynd and Harlech group to the close of the Tremadoc, and also shows in the last column, headed "Pass to Arenig," the number of species that pass to that formation, or the base of the Silurian as now recognized by many systematists. It will be seen that 11 genera and 16 species ($\frac{11}{16}$) pass to the Arenig; and this mode of expressing the connexion between the lower and succeeding formations is carried through all the Tables. Thus the right-hand column shows the number of species passing up to the succeeding formation, and the left-hand column (in all the Tables but this) those that came from an older or lower series. As this special Table, and also Table No. I., shows the commencement of life in the lowest rocks of the British Islands, there are no forms older than those expressed by the number 61 genera and 182 species. Their ancestors we know not; neither do we know whence was derived the fauna given under the 11 classes. The 6 smaller Tables distinctly show the more immediate relation of the several divisions of the Lower Cambrian rocks; nevertheless this completer Table is of value, showing, as it does, the whole range from the Longmynd rocks to the top of the Tremadoc.

I have endeavoured in my analysis of this Table, as in all the subsequent ones, to express in words the result of the figures, without which the Tables would merely enumerate the facts of occurrences of no value to the student of geology and palæontology; and although of necessity tautology must be frequent, yet the explanation, it is believed, will be clear. Throughout the whole of the Tables (and there is one for each epoch) the genera and species are given in the simplest form—the upper figure in each square (and under each formation) enumerating the number of genera in the respective horizons, and the lower figure demonstrating the number of species, thus: $\frac{4 \text{ genera}}{20 \text{ species}}$. This at once gives the census both zoologically and stratigraphically; *i.e.* there are 4 genera and 20 species in the given horizon or formation. In this

Table or record of the earliest rocks known, the numerous blanks show that the classes were not represented or had not appeared in the British Isles; but as we proceed through the formations we find that in time, or as life progresses, all the classes become represented. The study of these Tables with the description may be useful; and it is hoped they will be found not far from the truth, and exhibit the present state of our knowledge of the British species and their distribution in time.

Table VII.

Classes.	Genera.	Species.	Longmynd &c.	Menevian.	Lower Lingula-flags.	Upper Lingula-flags.	Lower Tremadoc.	Upper Tremadoc.	Pass to Arenig.
Plantæ?	2	2	2/3						
Protozoa	1	4	1/3	1/4	1/1				
Actinozoa.									
Echinodermata	3	3	......	1/1	......	......	2/2		
Annelida	9	12	4/5	3/3	2/2	2/2			
Crustacea	28	103	7/14	12/31	10/26	7/30	13/24	11/15	5/6
Bryozoa	1	1	......	......	......	1/1	1/1		
Brachiopoda	5	20	3/6	4/6	2/5	4/8	5/11	4/7	3/7
Lamellibranchiata	5	12	......	......	......	......	5/12		
Gasteropoda.									
Pteropoda	4	17	1/2	3/6	1/2	......	1/5	2/7	1/1
Heteropoda	1	6	......	......	......	......	1/2	1/2	1/1
Cephalopoda	2	2	...	......	......	......	......	2/2	1/1
	61	182	18/33	24/51	17/36	16/41	28/58	20/33	11/16

Arenig Rocks.

The Arenig or Skiddaw group of Sedgwick, immediately underlying the Llandeilo flags, forms the base of the true Silurian rocks. From Arenig-fawr Prof. Sedgwick and Mr. Salter obtained two of the characteristic fossils, *Calymene parvifrons* and *Ogygia Selwyni*. Sedgwick recognized these beds as being different from the Llandeilo above, and called them Arenig slates, believing them at the time to be the top of his Ffestiniog group. The group is distinctly recognized in the lead-mining district of the Stiperstones area, east of the Longmynd, underlying the true Llandeilo flags of Shelve and Corndon Hill, the Lower Llandeilo of Murchison. Salter first recognized the Arenig group near St. David's, passing upwards into the Llandeilo flags, which are so finely shown at Abereiddy Bay. The distinctness of the Arenig from the succeeding Llandeilo is clear, both physically and palæontologically. The following table exhibits most of the type forms occurring in the Arenig and the Llandeilo:—

	Arenig.	Lower Llandeilo.	Upper Llandeilo.	
Ogygia peltata	*	...	...	St. David's, Whitesand Bay.
—— Selwynii	*	...	...	Stiperstones and N. Wales.
Calymene parvifrons	*	...	...	Tai-hirion, near Arenig-fawr, Shropshire.
Æglina binodosa	*			
—— grandis	*			
—— caliginosa	*			
Trinucleus Murchisoni	*	...	...	Cefn-y-Gwynlle (Stiperstones).
—— Gibbsii	*	...	...	Whitesand Bay.
Orthoceras Avelinii	*	...	...	Stiperstones.
Obolella plumbea	*	*?	*	"
Cucullella anglica	*	...	...	"
Encrinites, ? sp.	*			
Asaphus tyrannus	...	*	...	Everywhere in L. Llandeilo.
—— peltastes	...	*	...	
Ogygia Buchii, var. convexa	...	*	...	
Calymene cambrensis	...	*	...	
Trinucleus favus	...	*	...	
Lichas patriarchus	...	*	...	
Bellerophon bilobatus	...	*		
Helicotoma	...	*	...	Fairfach, near Llandeilo.
Lingula granulata	...	*		
—— attenuata	...	*		
Orthis striatula	...	*		
—— calligramma	...	*		
Ctenodonta, ? sp.	...	*		
Ogygia (Asaphus) corndensis	...	...	*	Gilwern, near Builth.
—— Buchii	...	...	*	Abereiddy Bay.
Barrandia (Ogygia) radians	...	...	*	Builth and Abereiddy Bay.
—— Cordai	...	...	*	
Calymene duplicata	...	...	*	
Trinucleus fimbriatus	...	...	*	
Cheirurus Sedgwickii	...	...	*	
Ampyx nudus	...	...	*	
Agnostus Maccoyi	...	...	*	
Lingula Ramsayi	...	...	*	Abereiddy.
Bellerophon perturbatus	...	...	*	
Murchisonia simplex	...	...	*	Builth.
Modiolopsis inflata	...	...	*	
Didymograptus Murchisoni	...	...	*	
Orthis calligramma	...	...	*	
	12	14?	16	

"The great break in organic life between the Tremadoc slates and the Arenig or Skiddaw group determined Salter, after working out the two faunæ in the Tremadoc area in 1853, to regard the Arenig as the base of the Upper Cambrian of Sedgwick" *. Phillips regarded the Arenig as the upper or terminal member of the Middle Cambrian. Upon fossil evidence we may commence the Upper Cambrian of Sedgwick with the Arenig series, which is represented in the "Stiperstones" district. It was not until 1859 that Murchison and Salter described the fossils of that area, although Sedgwick in 1843 established the Arenig group, and subsequently obtained the same fossils from the Skiddaw Slates, which were described by M'Coy previous to 1851. Salter, from the majority of the fossils in the Tremadoc and Arenig groups, considered (and, I believe, rightly) that the Tremadoc is the "natural termination" of the Ffestiniog or Middle Cambrian series, and the Arenig the base of Sedgwick's Upper Cambrian. Lyell adopted this view in his manual; and Hicks and others have followed Salter in thus placing the two groups. In the Cambridge Catalogue the Arenig is treated partly as an intermediate group; and although it is 4000 or 5000 feet in thickness, yet the number of known species is few—about 60, all named, in the Woodwardian Catalogue.

That there is a perfect, continuous, and conformable succession from the Tremadoc into the Arenig rocks, admits of no doubt. It is true that this is seldom seen, even in the areas where they are typically developed. In the Shelve and Stiperstones districts, where 36 species are known, and in the Skiddaw area, yielding 76, no downward stratigraphical succession has been truly or definitely determined. The Arenigs seem to stand alone, especially in Westmoreland, where no older stratified rocks occur with which to compare them. In South Wales, however, at St. David's, their base rests upon the Tremadoc, and their summit is overlain by the Llandeilo beds of Abereiddy Bay, both clearly defined. The three divisions here have yielded no less than 96 species, 40 of which are Hydrozoa, and 31 Crustacea. Every Graptolite here makes its first appearance in time; none are known below the Arenig rocks. Six Crustacea out of the 31 are derived from the Tremadoc, and only 3 pass to the Llandeilo; therefore 22 species are peculiar to the Arenig. Indeed, out of the whole Arenig fauna, comprising 149 species, all but 38 are restricted to it. No more distinct group occurs in the British Islands.

Arenig Rocks of North Wales.

Professor Sedgwick, in 1852, described the Arenig slates and porphyries of North Wales as forming a distinct and well-marked subgroup in his previously named "Ffestiniog group," and as resting upon the underlying Tremadoc slate. It is also the "great group of roofing-slate and contemporaneous porphyry" described as occurring in the chains of Arenig, Arran Mowddwy, and Cader Idris, and in the Ffestiniog mountains, or the western base of the Arenigs and Arran, and probably the Stiperstone rocks. For many years

* Catalogue of the Collection of Cambrian and Silurian Fossils in the Geological Museum of the University of Cambridge, p. 18.

the elucidation of the true position of the Arenig group in North Wales remained a doubtful matter; probably the slates of Angers are of the same age. Mr. Salter did much in 1853 to unravel the structure of the Portmadoc area, and was enabled to correct the nomenclature and distribution of the so-called Lower Llandeilo rocks of the Penrhyn promontory, between Traeth-bach and Traeth-mawr, and of the country to the east, towards the Arrans. The succession across the Penrhyn promontory, from the Lingula-flags to the Arenig beds, is complete; and it is here that the Tremadoc slates and Arenig beds are typically developed in North Wales, the close of the Tremadoc and base of the Arenig being everywhere marked by the presence of a well-defined band of "grit," varying in thickness. The position of this grit had long been fixed by the late Mr. Salter in his Penrhyn section; but it was left for Professor Ramsay, in 1874, with Professor Hughes, Mr. Homfray, and myself, to trace this zone from Ogof-dua, near Criccieth, to Drws-dwgoed, under the Dolbenmain alluvium, and on to Tai-hirion; and in 1875 the late Mr. Ward and Mr. Herbert continued and completed the survey of it west of the Arenig and the Arrans on to Cader Idris, until last seen passing under the sea at Towyn. This line is the base of Sedgwick's Arenig slates and porphyries, and of the great roofing-slate series of the Ffestiniog area. Although occasionally obscured by faults, it is never lost, and must be traced by all who would understand the succession in North Wales between the Tremadoc and Arenig series. The fossils, when seen, at once determine the position—*Psilocephalus innotatus*, *Niobe Homfrayi*, *Asaphus Homfrayi*, *Lingulella Davisii*, and *Dictyonema sociale* illustrating the lower part of the Tremadoc, and *Angelina Sedgwickii*, *Asaphus Homfrayi*, and *Ogygia scutatrix* at Garth and Penclogwyn the upper; whereas, succeeding the grit-band above named, at Ty-obry, Tai-hirion, &c., *Calymene Murchisoni*, *Asaphus affinis*, *Dionide atra*, and *Æglina caliginosa* are the characteristic forms, being Arenig fossils. Only about 16 species connect the two groups. This physical line, when once determined, is a marked feature at the base of the Arenigs, dividing the two formations. Beneath the grit at Garth Hill and Deudreath occur the upper beds of the Upper Tremadoc slates (hard grey flags), rich in fossils, including *Asaphus Homfrayi*, *Angelina Sedgwickii*, *Ogygia scutatrix*, *Lingulocaris lingulæcomes*, *Cheirurus Frederici*, and *Conularia corium*. These hard grey beds at the top, some would separate from the Tremadoc group, purely upon palæontological grounds, or because certain species above named are common to the two horizons. Some regard must, however, be paid to stratigraphical evidence.

There is no distinct passage-bed containing fossils between the Upper Tremadoc and the Arenig. Through the Portmadoc district the two groups are separated by a peculiar band of felspathic grit, which intervenes to cut off the upper (volcanic) series from the true Tremadoc slates below. This felspathic grit, variously conditioned, may be traced along Yr-allt-wen, above Tremadoc, and across the estuary of Treath Maw; it constitutes the brow of the Garth, and ranges under the foot of Moelwyn to the Manod mountains on the east. This zone, all along its course, indicates and ushers in a new set of conditions, physical and palæontological. No Graptolites occur below this line anywhere; but in the black slates immediately overlying it at Garth &c. they occur in plenty, associated with certain species of *Homalonotus*, *Asaphus*, *Calymene*, *Æglina*, and *Dionide*, accompanied by *Conularia* and Lamellibranchs; and among the lower beds of the volcanic rocks of the Manods *Calymene parvifrons* and *Trinucleus Murchisoni* occur, accompanied still further eastward by *Ogygia Selwynii*, the species, of all others, which characterizes the Arenig rocks of Shelve and Skiddaw, and occurs at Llanfaelrhys, in South Caernarvonshire, associated with *Lingula attenuata* and *Graptolithus Murchisonii*. This classification is borne out by the persistent position of the grit which everywhere separates the two horizons palæontologically as well as stratigraphically, the mass of the Arenig with its peculiar fauna not occurring until the grit is passed. No species of Rhabdophora is known below this grit (their first appearance being in the Arenig rocks); and although the Arenig Graptolithidæ are rare in North Wales (4 species), as compared with Skiddaw (27 species), or with South Wales, St. David's (18 species), still the distinct Crustacea must be held as significant. Again, comparing the value of the same formation in North and South Wales, it is important to remember that, of the whole Arenig fauna in South Wales (97 species), only 5 north-west forms are common to the two areas: these are *Calymene parvifrons*, *Ogygia Selwynii*, *Æglina caliginosa*, *Lingulella Davisii*, and *Orthis lenticularis*. 26 Trilobites, 8 Brachiopoda, 38 Rhabdophora, and 3 Pteropoda are peculiar and confined to South Wales. Thus amongst the same group of rocks the correlation of species is a difficult question, even over so small a geographical area as Wales.

The dark slates at Ty-obry, which immediately overlie the grit, contain *Calymene parvifrons*, *Æglina caliginosa*, and *Dionide atra*, associated with *Diplograptus mucronatus*, *Climacograptus confertus*, and *Glossograptus ciliatus*, all Lower-Arenig species. *Palæarca socialis* and a species of *Ctenodonta* are the only North-Welsh bivalves, and *Conularia corium* and *C. margaritifera* the only two Arenig Pteropods known in North Wales. None of these occur in the Arenig series of St. David's, and none pass to the Llandeilo group in any area.

The researches of Dr. Hicks at St. David's have resulted in greatly advancing our knowledge of Sedgwick's group in that area*. In his paper upon "the Succession of the Ancient Rocks of St. David's," Dr. Hicks draws attention to the history of the names Arenig and Llandeilo groups, and explains the manner in which the two series were confounded by one of the authors who have written upon them, and how the slates above and below the Arrans and Arenigs were by him and the Geological Survey classed as equivalent to Llandeilo flags of Builth &c.

The St.-David's Arenigs consist mostly of black slates, resting

* Quart. Journ. Geol. Soc. vol. xxxi. pp. 167–194.

conformably upon the Tremadoc group on the N. and N.E. side of the anticlinal, and they may be continuously traced for many miles. They occur also at Ramsey Island, and are there 4000 feet thick, chiefly deep-sea deposits, and must have been of great duration, as proved by their varied and distinct faunas.

Dr. Hicks divides the Arenig group, through its zonal contents, into three subgroups, the Lower, Middle, and Upper Arenig. The lower, or black slaty Arenig, strikes E.N.E. and W.S.W., and has a vertical dip. The cliffs at Whitesand Bay and Road-uchaf, in Ramsey Island, yield the chief fossils. Numerous species of Graptolites have been obtained from this lower subgroup; the Trilobites *Asaphus Homfrayi*, and *Ogygia scutatrix*, with *Conularia Homfrayi* and *Lingulella Davisii*, especially characterize this lower division, and are associated with *Phyllograptus stella*, *Trigonograptus ensiformis*, *Callograptus radiatus*, and *Ptilograptus Hicksii*. Dr. Hicks enumerates 25 species from this division, 28 from the middle, and 33 from the upper*. *Asaphus Homfrayi*, *Ogygia scutatrix*, and *Conularia Homfrayi* are Upper-Tremadoc as well as Lower-Arenig forms, and connect the two formations. I am not aware that *Lingulella Davisii* ever again appears above this horizon in the Cambro-Silurian rocks. The middle slaty and flaggy groups are also best seen at Whitesand Bay. In 1860 Mr. Gibbs, the late fossil-collector for the Survey, obtained a few fossils here. The characteristic Trilobite *Trinucleus Gibbsii* was first obtained by him at Whitesand Bay, and subsequently in the Skiddaw beds. This locality has furnished *Ogygia bullina*, *O. peltata*, *Æglina grandis*, *Trinucleus Gibbsii*, *T. Sedgwickii*, *Ampyx Salteri*, *Lingula petalon*, and *Orthoceras sericeum*, with 6 genera and 11 species of Rhabdophora; all the above are essentially characteristic of, and confined to the middle subdivision. Of the Graptolites the chief are *Tetragraptus crucifer*, *T. serra*, *T. Hicksii*, *T. Halli*, *Clematograptus implicatus*, *Callograptus elegans*, and *C. Salteri*.

Lithologically the Upper Arenigs resemble the Lower, being fine-grained dark shales, 1500 feet thick; they underlie the true Lower Llandeilo near Abereiddy Bay, and are conspicuous for the new and distinctive fauna and the first appearance of many genera of Trilobites, distinctly marking a complete and progressive change from the fauna of the Tremadoc below towards the introduction of succeeding Llandeilo forms. Llanvirn quarry has yielded to Dr. Hicks a rich group of species "distinct from any previously discovered in any part of the Arenig series at St. David's"†. Most of the genera are new; and several genera which appear for the first time, culminate in the Llandeilo and Caradoc rocks; these are *Illænus*, *Illænopsis*, *Barrandia*, and *Phacops*, each having a representative species, and *Placoparia*, this last a genus new to Britain, hitherto only known in France, Bohemia, and Spain. The occurrence here of this genus is

* These numbers are doubtless in excess; many forms must give way on critical examination, numerous species being made upon fragments only. Mr. Lapworth has already reduced them considerably. The Arenig of St. David's *may* yield 25 species; the whole Arenig probably about 50 species.

† Dr. Hicks, Quart. Journ. Geol. Soc. vol. xxxi. p. 174.

important as bearing both upon distribution and correlation. Again, the Gasteropoda first appear in Britain in the Upper Arenigs of St. David's (*Pleurotomaria llanvirnensis,* and *Ophileta* or *Raphistoma*). Yet, strangely, we have no record of any Lamellibranchs through the whole of the Arenig group in South Wales; 4 species are known from the Stiperstones area, and 2 from Ty-obry, in North Wales. It will be remembered that no less than 12 species occur below in the Lower Tremadoc rocks of the same area. The value of this upper division of the Arenig group in South Wales is enhanced by its resemblance to Barrande's Étage D 1 (Bohemia), and its close relation to the fauna found in the Arenig slates in North-west France. The recognized presence of this stage in Britain enables us to correlate our beds with those on the continent, and thus establish a general succession for the Western-European and Western-British rocks of this age.

This result is due to the researches of Dr. Hicks, as detailed in his valuable papers upon the history and succession of the ancient rocks of St. David's. Carefully constructed tables, prepared for the purpose of testing the value of the Arenig group and its relation to the Tremadoc below and Llandeilo above, clearly show that it stands almost alone; for of the 55 known species of Hydrozoa in the Arenig, only 2 species pass to the Llandeilo (*Didymograptus Murchisoni* and *Climacograptus confertus*). The first appearance and the abundance of the Rhabdophora in the Arenig rocks would alone justify the position now assigned to it as the base of the Lower Silurian rocks; only 1 species is known to occur in the Tremadoc group (*Dendrograptus*, from the Shineton Shales of Shropshire). The crustacean fauna is equally conclusive; out of 50 Arenig forms known, only 2 (*Trinucleus Ramsayi*, Hicks, and *Homalonotus bisulcatus*, Salt.) unite the Arenig and Llandeilo through the Trilobita. Out of the 18 species of Brachiopoda, only 3 pass to the Llandeilo, viz. *Lingula brevis*, *L. attenuata*, and *Orthis calligramma.* No Lamellibranch, Pteropod, Heteropod, Gasteropod, or Cephalopod (of which united, there are 30 species) passes to the Llandeilo. Thus, out of the known fauna of 149 species, only 16 pass upwards into or are common to the Llandeilo beds. 150 species make up the entire known fauna of the Arenigs; their distribution is as follows:—125 species occur in the North and South Wales Arenigs, 34 from various localities in North Wales (Tremadoc, Ty-obry, and Tai-hirion), and 94 in South Wales; the Skiddaw species number 50 and the Stiperstones 36. These two latter localities are important; they are widely separated, and very few species occur in common. Of the 50 Skiddaw species of all classes, only 9 occur in the area west of the Stiperstones in Shropshire; this is due chiefly to the rich Graptolite fauna, which group is largely represented, no less than 52 species occurring in the Skiddaw beds alone. West of the Stiperstones only 6 species are known; and they have an important bearing upon distribution: they are *Didymograptus patulus*, Hall, *D. geminus*, *D. hirundo*, *D. constrictus*, *D. Murchisoni*, and *Clematograptus implicatus*. *Diplograptus dentatus* also occurs at Tremadoc and

Tai-hirion in North Wales, and ranges to both Llandeilo and Caradoc; *Didymograptus patulus*, *D. hirundo*, and *Clematograptus implicatus* are also present at St.-David's*. Few Hydrozoa occur in the North-Wales Arenigs; Ty-obry, Tremadoc, and Tai-hirion yield the few that have been met with. 23 species range through the St.-David's series, 2 of which only are common to the Stiperstones area, viz. *Didymograptus patulus* and *D. hirundo*; and 5 or 6 ally them to Skiddaw. There is thus little in common between the Arenigs of Skiddaw and North Wales, few species connecting them. The relation, however, between the Skiddaw species and those of St. David's is closer, 5 or 6 being Graptolites, and 2 Trilobites (*Ogygia Selwynii* and *Trinucleus Gibbsii*). These, we must remember, are the two largest groups, and have been most searched for, at St. David's especially, by Dr. Hicks, and in the Skiddaw beds by Dr. A. Nicholson, Mr. Dover, and the Survey (through the late Mr. Ward).

The value of the Arenig group is still more apparent when we consider the development of life that accompanied those physical conditions and changes which took place at the close of the Lingula-flag and Tremadoc epochs. We know that no less than 40 genera *make their first appearance in the Arenig rocks in the British Islands.* These 40 genera belong to the following 6 classes:—

Hydrozoa 16: *Callograptus*, *Dendrograptus*, *Phyllograptus*, *Didymograptus*, *Azygograptus*, *Ptilograptus*, *Trigonograptus*, *Tetragraptus*, *Climacograptus*, *Nemagraptus*, *Dicellograptus*, *Clematograptus*, *Diplograptus*, *Glossograptus*, *Dichograptus*, and *Loganograptus*.

Annelida 4: *Helmintholithes*, *Stellascolites*, *Nereites*, and *Palæochorda*.

Crustacea 11: *Æglina*, *Trinucleus*, *Barrandia*, *Calymene*, *Phacops*, *Placoparia*, *Illænus*, *Illænopsis*, *Homalonotus*, *Beyrichia*, and *Caryocaris*.

Brachiopoda 2: *Dinobolus* and *Siphonotreta*.

Lamellibranchiata 2: *Ribeiria* and *Redonia*.

Gasteropoda 3: *Ophileta*, *Pleurotomaria*, and *Rhaphistoma*.

The succeeding Llandeilo, as we shall see, was equally prolific, no fewer than 48 new genera accompanying the complete change of conditions at the close of the Arenigs and commencement of the Llandeilo. This change was bridged over by only 8 genera and 9 species passing to the Llandeilo in any area; 4 are Hydrozoa, 2 Crustacea (*Trinucleus Ramsayi* and *Homalonotus bisulcatus*), 3 Brachiopoda (*Lingula brevis*, *L. petalon*, and *Orthis calligramma*); and only 3 range into the Caradoc. As before stated, the relation of the Arenig to the Tremadoc is through 16 species, 6 of which are Brachiopoda, 6 Crustacea, and 4 bivalve Mollusca. Thus 122 species out of 150 are strictly Arenig forms or confined to that horizon.

* Five other Skiddaw species occur west of the Stiperstones, and, with the 6 Graptolites, tend to connect the Arenigs of Shropshire with those of Westmoreland. They are the Annelida *Scolithus linearis*, Salt., and *Helmintholithus*, with *Agnostus Morei*, Salt., *Ogygia Selwynii*, Salt., and *Æglina binodosa*.

Nothing can be more conclusive as to the value of the Arenig group than the distinctive part played by its characteristic fauna and its distinct stratigraphical position. Since the determination by Hicks of the St.-David's fauna, Mr. Marr of Cambridge recognized some fossiliferous shales south-east of Caernarvon, in three localities on the banks of the Sciont; these shales contain Arenig species. The Trilobita and Brachiopoda indicate Arenig affinities; and the *Orthoceras caereesiense* occurs only in the Arenigs of Llanvirn, near St. David's. The genus *Caryocaris* (a new species of which has occurred here, *C. Marrii*) hitherto has not occurred out of the Skiddaw Slates of Cumberland (*C. Wrightii* being the type). The associated Graptolites are those of the Skiddaw rocks also, viz. *Didymograptus bifidus*, *D. indentus*, and the Llandeilo form *D. Murchisonii*. The genus *Barrandia* would help to place these beds either in the Arenig or the lower part of the Llandeilo group. This locality is suggestive of the Arenig or Llandeilo beds striking from Caernarvon to Bangor and Aber, west of the great fault that runs from Dingle on the S.W. to Aber on the N.E.

Arenig of South Wales at St. David's.

The following table enumerates all the species at present known in the Arenig rocks of St. David's; it is convenient to subdivide the group into 3 series, both on lithological and palæontological grounds. It will be seen how distinct the fauna of each division or series appears. The total number of species at St. David's is 70. The lower Arenig has yielded 16 species, the middle 24, and the upper 33. 14 species are peculiar or confined to the lower series, 21 to the middle, and 30 to the upper. No species out of the 70 occurs in all three divisions. We thus see how distinctive a group of fossils each subdivision contains. For the construction of the Arenig Table (No. VIII., p. 115) I have selected 18 localities from which the Arenig species have been obtained, and tabulated 8 of the most important. The four type areas, where the Arenig rocks are present and well developed, are:—

1. *Westmoreland*: Skiddaw.
2. *Shropshire*: Shelve area.
3. *North Wales*: Tremadoc, Tai-hirion, &c.
4. *South Wales*: Ramsey Island and St.-David's area.

The chief localities for fossils are the following 18, comprised in the above 4 areas:—

1. *Westmoreland*: Skiddaw, Longside, Keswick, Outerside, Scaafel, Whiteside, and Braithwaite River.
2. *Shropshire*: Shelve area (west of Stiperstones), Mytton Dingle, Perkins Beech.
3. *North Wales*: Tremadoc, Garth, Ty-obry, Tai-hirion.
4. *South Wales*: Ramsey Island, Llanvirn, Whitesand Bay, and St. David's.

Arenig Species, St. David's.

Species.	Lower.	Middle.	Upper.
RHABDOPHORA.			
Didymograptus extensus, *Hall*	*		
—— affinis, *Nich.*	...	...	*
—— patulus, *Hall*	...	*	*
—— bifidus, *Hall*	...	...	*
—— pennatulus, *Hall*	*	...	*
—— sparsus, *Hop.*	*		
—— indentus, *Hall*	...	...	*
—— Nicholsoni, *Lapw.*	...	...	*
Phyllograptus stella, *Hall*	*		
—— typus, *Hall*	*		
Trigonograptus truncatus, *Lapw.*	*		
—— ensiformis, *Hall*	*		
Ptilograptus Hicksii	*		
Dicellograptus divaricatus, *Hall*	...	...	*
Diplograptus dentatus, *Brongn.*	...	...	*
Climacograptus confertus, *Lapw.*	...	...	*
Clematograptus implicatus, *Hopk.*	...	*	
Tetragraptus crucialis, *Salt.*	...	*	
—— Halli, *Hopk.*	...	*	
—— Hicksii, *Hopk.*	...	*	
—— bryonoides, *Hall*	...	*	
—— quadribrachiatus, *Hall*	...	*	
—— serra, *Brongn.*	...	*	
Glossograptus ciliatus, *Emm.*	...	...	*
CRUSTACEA.			
Asaphus Homfrayi, *Salt.*	*		
Agnostus hirundo, *Salt.*	...	*	
Ampyx Salteri, *Hicks*	...	*	
Æglina grandis, *Salt.*	...	*	
—— Boia, *Hicks*	...	*	
—— obtusicaudata, *Hicks*	...	...	*
Barrandia Homfrayi, *Hicks*	...	...	*
Calymene Hopkinsoni, *Hicks*	...	...	*
—— parvifrons, *Salt.*	...	...	*
—— ——, var. Murchisoni, *Salt.*	...	...	*
——, sp.	...	*	
Cheirurus, sp.	...	*	
Ogygia scutatrix, *Salt.*	*		
—— peltata, *Salt.*	...	*	
—— bullina, *Salt.*	...	*	
Illænus Hughesii, *Hicks*	...	...	*
Illænopsis? acuticaudata, *Hicks*	...	...	*
Placoparia cambrensis, *Hicks*	...	...	*
Phacops llanvirnensis, *Hicks*	...	...	*
Trinucleus Gibbsii, *Salt.*	...	*	
—— Sedgwickii, *Salt.*	...	*	
—— Etheridgei, *Salt.*	...	...	*
—— Ramsayi, *Hicks*	...	...	*
——, sp.	*		
Beyrichia, sp.	...	...	*
Carried forward	11	18	22

Arenig Species, St. David's (continued).

Species.	Lower.	Middle.	Upper.
Brought forward	11	18	22
BRACHIOPODA.			
Lingulella Davisii, *M'Coy*	*		
Lingula petalon, *Hicks*	*	*	
Lingula attenuata, *Sow.*	...	...	*
Discobolus? Hicksii, *Dav.*	...	...	*
Discina, sp.	...	...	*
Orthis lenticularis, *Dalm.*	*		
——, sp.	...	...	*
——, sp.	...	*	
Obolella plicata, *Hicks*	*		
Siphonotreta, sp.	...	*	
GASTEROPODA.			
Ophileta, sp.	...	...	*
Pleurotomaria llanvirnensis, *Hicks*	...	...	*
PTEROPODA.			
Conularia Homfrayi, *Salt.*	*		
—— llanvirnensis, *Hicks*	...	...	*
Theca caereesiensis, *Hicks*	...	...	*
—— Harknessii, *Hicks*	...	*	
HETEROPODA.			
Bellerophon multistriatus, *Salt.*	...	*	
—— llanvirnensis, *Hicks*	...	...	*
CEPHALOPODA.			
Orthoceras sericeum, *Salt.*	...	*	
—— caereesiense, *Hicks*	...	...	*
ANNELIDA.			
Buthotrephis, sp.	...	...	*
	16	24	33

The intimate stratigraphical conformity at St. David's between the Tremadoc and Arenig rocks, and between the latter and the overlying Llandeilo series, is clear and determined, both on the mainland and on Ramsey Island, where both the Tremadoc and the Arenig occupy a considerable area. Much of the centre of the island is composed of the Arenig series, and is prolific in fossils. The slates of St. David's are black and probably of deep-sea origin. The subdivision here by Dr. Hicks into Lower, Middle, and Upper is based upon the distribution of the organic remains and the relation to the Llandeilo above. This comparison is important in its bearing upon the value and meaning of the terms Arenig and Lower Llandeilo as applied to at least four areas and groups of rocks in England and Wales, viz.:—Westmoreland, or the Skiddaw group; Shropshire, or the Stiperstones series; North Wales, or the Tremadoc and Ffestiniog areas; and South Wales, or the St.-David's beds. Formerly the Geological Survey regarded three of the groups in the areas above mentioned as belonging to rocks termed Lower Llandeilo by Sir R. Murchison; they were mapped as Llandeilo simply, the Survey not recognizing the two divisions termed Lower and Upper on the maps, as they are not separable or distinguishable in the field over large areas. The exact position of the Arenig group was, and has for many years been, a doubtful question; and it is due to the continued researches of Messrs. Salter and Homfray in North Wales, and of Dr. Hicks in South Wales, that the name and position assigned to these beds by Prof. Sedgwick in 1843 is now revived and definitely established, and that the Arenig group of rocks and fossils has now had assigned to it its true stratigraphical place above the Tremadoc group and below the Llandeilo proper, and with a fauna recognized as peculiarly its own. The Llandeilo of Murchison and the Survey (first named in 1843) did not really include any of the Arenig proper as determined in North Wales in 1843, 1846, and 1852, or as occurring in the chain of the Arrans, Arenig, Cader Idris, and in the Ffestiniog region (typical districts). The term "Lower Llandeilo" of Murchison included Prof. Sedgwick's "Arenig," not as first intended; and Prof. Ramsay, in the first edition of his 'Geology of North Wales'*, states that "since 1848 the Survey considered the slates close below and above the Arans and Arenigs as equivalent to the Llandeilo flags of Builth and Shelve"†.

Mr. Salter, however, in the appendix to the same work in 1866, pp. 253–257, under the section "Lower Llandeilo" and plates 8–12, clearly showed the importance of truly correlating the Arenig group, eliminating it partly from the Upper Tremadoc below and from the so-called Llandeilo above.

There is now no doubt whatever about the horizon or position of the Arenig rocks. They are entirely distinct from the Tremadoc group of Sedgwick, and were claimed as Lower Llandeilo by Murchison. They are the "Arenig and Skiddaw" group of Sedgwick, established by him in 1834, and confirmed through subsequent research in the Skiddaw area, and of which the fossils were described by M'Coy before 1851. Priority therefore under all heads is due to the researches of Prof. Sedgwick. Finally Salter described the majority of the fossils of both the Arenig and Tremadoc groups, showing in the clearest manner that the Tremadoc rocks were the natural termination of the Ffestiniog or "Middle Cambrian" series, and the Arenig group the base of the "Upper Cambrian" or "Lower Silurian" of Murchison; these rocks through their fossils, have their equivalents, as shown by Salter, in the Quebec group of Canada.

Plantæ.—None.

Protozoa.—None.

Hydrozoa.—Subsequent to the change of conditions which terminated the Tremadoc period, or at the coming-in or commencement of the Arenig deposits, no less than 18 genera and 42 species of

* Mem. Geol. Surv. of Great Brit. vol. iii. p. 6 (ed. 1, 1866).

† Sir R. Murchison, in 1834, termed the Llandeilo flags "Trilobite schists" in his description of the Shelve country, the Carneddau (Builth), and the neighbourhood of Llandeilo; and under this name were included (near Shelve) the strata as low as the base of the Stiperstones, the whole of these rocks being older than the Caradoc sandstone.

Hydrozoa first appeared in the British Arenig sea, and that without any known previously-existing Cœlenterate fauna. We have no clue to the area or region whence they migrated; possibly Canada may be selected as one, at least, of the probable areas for their origin and dispersion. We regard the Quebec group of rocks as the equivalent in time of our Arenig series; and they contain the same species of Graptolites in great profusion. We cannot look to Scandinavia for such an assemblage; and although the Bohemian Graptolitic fauna was extensive, still, on the whole, I should regard the Canadian, through certain genera and species, as being the source of dispersion and migration. There is intimate agreement between the faunas of many of the American and our own Palæozoic rocks; and this is notably the case with the Arenig and its Graptolites.

Thirteen genera and 28 species of Graptolites occur in the Skiddaw group, showing that more than two thirds of the known genera and species are in the almost barren slates of the Keswick area; for, with the exception of 10 species of Annelida (all tracks and burrows), 9 species of Crustacea, and 2 Brachiopoda, no other forms are known—neither Lamellibranch, Gasteropod, Pteropod, or Heteropod, so far as we know, ever having appeared in the Skiddaw series west of the Stiperstones in the Shelve area*. The Arenig rocks are there clearly exhibited, but yield only a small series of Hydrozoa. Only 3 genera and 6 species have yet been collected; they are *Diplograptus pristis*?, *Didymograptus patulus*, *D. geminus*, *D. hirundo*?, *D. constrictus*, and *Clematograptus implicatus*. The Crustacea eminently characterize the Shelve Arenigs; and it is through the 6 genera and 9 species of Trilobita and the stratigraphical position that the age of the beds is clearly determined: 3 of the 7 genera that occur here are also in the Skiddaw rocks—*Agnostus Morei*, *Ogygia Selwynii*, and *Æglina binodosa*. Next to North Wales the Shropshire Arenigs contain the smallest number of species; but they are distinctively characteristic.

North Wales, from the Tremadoc and Ffestiniog areas at Tremadoc, Ty-obry and Tai-hirion, has yielded only 4 genera and 4 species.

Next to the Skiddaw rocks and the Westmoreland area the chief development of the Arenig group occurs in South Wales on the St.-David's promontory, at Llanvirn, Whitesand Bay, Trwyn-hwrddyn, and Porth Melgan, and the rich locality of Ramsey Island. These several localities have yielded, to the researches of Dr. Hicks, Mr. Hopkinson, Mr. D. Homfray, and others, about 8 genera and 18 species of Graptolites. Only 3 species are common to North and South Wales, namely *Diplograptus dentatus*?, *Climacograptus confertus*, and *Glossograptus ciliatus*; 6 show the relation of the Skiddaw rocks with South Wales, viz. *Didymograptus affinis*, *D. bifidus*, *D. patulus*, *Tetragraptus quadribrachiatus*, *Phyllograptus typus*, and *Diplograptus dentatus*?; and 7 are common to the Stiperstones area and South Wales, viz. *Didymograptus patulus*, *D. affinis*, *D. hirundo*, *D. bifidus*, *Diplograptus dentatus*, *Clematograptus implicatus*, and

* Lords Hill, Bog Mine, Dingle, Ritton Castle, Corndon, &c.

Climacograptus confertus. Out of the entire fauna of the Arenig Rhabdophora only 2 or 3 genera and species pass to the Llandeilo rocks.

Echinodermata.—No record whatever of this class in the Arenig rocks.

Annelida.—The whole group, of which 9 genera and 11 species are described, possesses no zoological value; they are simply worm-burrows, worm-tracks, or trails of Mollusca. Ten of the 11 so-called Annelide species occur in the Skiddaw Slates, the one unrepresented form being *Buthotrephis* from St. David's. *Scolithus linearis* and *Helmintholithes* are in the Stiperstone beds also. No species has occurred in North Wales; and no species pass up from the Tremadoc and Lingula-flags below.

Crustacea.—The Arenig rocks have unequally distributed through them 14 genera of Trilobites and 48 species, Ostracoda 2 (*Beyrichia* and *Primitia*) and the Phyllopod *Caryocaris Wrighti* increasing the Crustacean fauna to 17 genera and 51 species. The *special* Trilobita, however, number 41 species (6 coming up from the Tremadoc and 2 passing to the Llandeilo, namely *Trinucleus Ramsayi* and *Homalonotus bisulcatus*). No group in any of the British rocks is so specialized as the Arenig Crustacea. The Skiddaw rocks hold 9 species, representing 7 genera *; the Shelve Arenigs have 10 species and 7 genera †, both areas showing either imperfect collecting, or poverty in representation (which is by no means likely). The few species (mostly single) known or occurring in each genus clearly shows how large a fauna may be expected if the more fossiliferous beds could be found in these somewhat barren rocks. This applies equally to North Wales, where 9 genera are only represented by 11 species. In South Wales (St. David's) the three areas have yielded 15 genera and 35 species. Circumstances have favoured collecting in this region; and the known fauna is increased thereby. The Northern or Skiddaw fauna is allied to the Shelve or Shropshire group through 3 species only (*Agnostus Morei*, *Ogygia Selwynii*, and *Æglina binodosa*). The *special* Skiddaw forms are 4 only (*Caryocaris Wrightii*, *Phacops Nicholsoni*, *Niobe Doveri*, and *Æglina* sp.); but 9 occur in these beds. The *special* Shelve species are *Trinucleus Murchisoni*, *Illænus perovalis*, *I. Thomsoni*, and *Cheirurus* sp.; but 10 species occur in the Shelve beds. The special North-Wales species are also only 2, *Asaphus affinis* and *Caryocaris Marrii*. The special South-Wales species are *Agnostus hirundo*, *Asaphus Homfrayi*, *Ogygia scutatrix*, *O. peltata*, *O. bullina*, *Asaphus menapiæ*, *Trinucleus Sedgwickii*, *Ampyx Salteri*, *Æglina boia*, *Æ. grandis*, *Æ. obtusicaudata*, *Barrandia Homfrayi*, *Calymene ultima*, and *C. vexata*; the occurrences in South Wales, however, are 35 species in 15

* *Caryocaris Wrightii*, *Agnostus Morei*, *Ogygia Selwynii*, *Trinucleus Gibbsii*, *Æglina caliginosa*, Salt., *Æ. binodosa*, *Æ.* sp., *Phacops Nicholsoni*, and *Niobe Doveri*.

† *Agnostus Morei*, *Oyygia Selwynii*, *Trinucleus Murchisoni*, *Æglina binodosa*, *Calymene parvifrons* and var. *Murchisoni*, *Illænus perovalis*, *I. Thomsoni*, *Cheirurus Frederici*, and *C. pectinatus*.

genera. Eleven new genera of Crustacea, 10 of which are Trilobita, appeared in the Arenig sea: they are *Æglina*, *Angelina*, *Trinucleus*, *Barrandia*, *Calymene*, *Phacops*, *Placoparia*, *Illœnus*, *Illœnopsis*, *Homalonotus*, and the Phyllopod *Caryocaris*, which, with *Placoparia*, never passed to higher rocks.

Brachiopoda.—7 genera, *Lingulella*, *Lingula*, *Orthis*, *Obolella*, *Discina*, *Siphonotreta*, and *Dinobolus*, represented by only 18 species, are all that can be recorded of this class through the Arenig rocks. All the genera and 12 of the 18 species occur in the St.-David's area. Only 2 species are known in the Skiddaw rocks, *Lingula brevis* and a *Discina*; and 5 in the beds west of the Stiperstones; they are *Lingula attenuata*, *Orthis alata*, *O. calligramma*, *O. striatula*, and *Obolella plumbea*. The 5 North-Wales forms are *Lingulella Davisii*, *L. lepis*, *Orthis lenticularis*, *O. calligramma*, and *Obolella plicata*, Tai-hirion yielding 4 of the 5. *Lingula petalon*, *L. brevis*, and *Orthis calligramma* are all that pass to the Llandeilo rocks; but 9 come from the Tremadoc; therefore the special forms are only 6—*Siphonotreta micula*, *Dinobolus Hicksii*, Dav., *Discina* sp., *Orthis striatula*, *O. remota*, and *O. alata*. The new genera are *Dinobolus* and *Siphonotreta*.

Lamellibranchiata.—*Ribeiria complanata*, *Modiolopsis trapeziformis*, *Palœarca amygdalus*, and *Redonia anglica* occur in the Shelve Arenigs. *Palœarca socialis* and a species of *Ctenodonta* occur only at Ty-obry in North Wales. None are known either in the Skiddaw rocks or in South Wales, 6 species being the entire bivalve fauna. *Ribeiria* and *Redonia* first appear in the Arenig rocks.

Gasteropoda.—Only 4 genera and 4 species are at present known. *Pleurotomaria llanvirnensis*, Hicks, and *Ophileta* sp., occur at Llanvirn, St. David's; *Rhaphistoma*, Skiddaw only; and the Stiperstone form is *Euomphalus corndensis*, Sow. No species known in North Wales.

Pteropoda.—4 species of *Conularia* and 4 of *Theca* constitute the Arenig Pteropod fauna. The Shelve species are *Theca simplex*, Salt., and *T. vaginula*, Salt. Those occurring in North Wales are *Theca vaginula*, Salt., *Conularia corium*, Salt., and *C. margaritifera*, Salt. *Theca Harknessii*, Hicks, *T. caereesiensis*, Hicks, *Conularia llanvirnensis*, Hicks, and *C. Homfrayi*, Salt., range through the St.-David's Arenigs.

Heteropoda.—4 species of *Bellerophon* in the Stiperstone beds and 2 in the St.-David's are all that are known. The Stiperstone species are *B. hippopus*, Salt., *B. bilobatus*, Sow., *B. carinarioides*, and *B. perturbatus*, Sow. The South-Wales species are *B. multistriatus*, Salt., and *B. llanvirnensis*, Hicks. No species yet known in North Wales.

Cephalopoda.—*Orthoceras Avelinii* and *O. encrinale* occur in the Corndon area (Shropshire). *O. sericeum* and *caereesiense* are only known at St. David's, South Wales; an undeterminable form occurs at Ty-obry (Tremadoc, North Wales). None in the Skiddaw beds.

The distinctive value of the Arenig fauna is shown in the fact that only 8 genera and 9 species pass to the Llandeilo; and 4 of these species are Hydrozoa, 2 are Crustacea (*Trinucleus Ramsayi* and *Homalonotus bisulcatus*), and 3 Brachiopoda (*Lingula brevis*, *L. attenuata*, and *Orthis calligramma*). Looking, therefore, at the number of genera (63) and species (150) in the whole Arenig, the change or extinction at the close of the period has scarcely any parallel in the Palæozoic rocks. The accompanying Table shows the numerical value of the Arenig species, the 63 genera and 150 species being distributed through four well-determined areas, and showing the fauna to be, in the

Skiddaw beds	31 genera and	49 species.
Stiperstones area ..	26 "	41 "
North Wales	21 "	26 "
South Wales	37 "	76 "

Only 8 genera and 9 species transgressed or passed to the succeeding formations; and 11 genera and 16 species came in with the advent of the group from the Lower Cambrian series. The true numerical faunal value of the Arenig group is therefore 51 genera and 133 species; those forms, or the 9 species, which pass to higher formations do not affect the Arenig beyond linking it to the next group in succession.

TABLE VIII.—*Arenig*.

From Upper Tremadoc.		Genera.	Species.	Geographical Distribution.				Pass to	
				Skiddaw beds.	West of the Stiperstones.	North Wales.	South Wales.	Llandeilo.	Caradoc.
	Plantæ								
	Protozoa								
	Hydrozoa	18	42	13/28	7/11	4/4	10/24	4/4	
	Actinozoa								
	Echinodermata..................								
	Annelida	9	11	8/10	2/2	...	1/1		
4/6	Crustacea	17	50	7/9	7/10	9/11	15/35	2/2	1/1
	Bryozoa............................								
3/6	Brachiopoda......................	7	18	2/2	2/5	3/5	7/12	2/3	2/2
	Lamellibranchiata	4	6	...	4/4	2/2			
	Gasteropoda......................	4	4	1/1	1/1	...	2/2		
2/2	Pteropoda.........................	2	8	...	1/2	2/3	2/4		
1/1	Heteropoda	1	6	...	1/4	...	1/2		
1/1	Cephalopoda	1	5	...	1/2	1/1	1/2		
11/16	....	63	150	31/51	26/41	21/26	39/82	8/9	3/3

Llandeilo.

It may be thought by some superfluous to discuss the history of the Llandeilo rocks proper; but it is part of my purpose to do so, for two reasons:—first, to show their true relations (affinities and differences) to the Arenigs, which they overlie and with which they have long been confounded; and, secondly, to show the geographical distribution of the Llandeilo species and their palæontological relations to the Caradoc rocks above and the Arenigs below. The three classical localities for the Llandeilo rocks and fossils are Llandeilo, Builth, and Abereiddy Bay north of St. David's. Each of these areas possesses a characteristic and definite fauna; on the whole the species in each locality are much the same; still the facies is peculiar in each. It is also of much interest to clearly understand the true position of the great band of dark roofing-slate of the "Ffestiniog quarries" &c. that underlies the Caradoc or Bala series, occupying the position of the Llandeilo flags. "It is probable that the lowest portion of the Llandeilo group may occur in the Arenig and Ffestiniog mountains, and also in the Arrans;" but the evidence is slight and the materials (in the shape of fossils) are scanty. Salter obtained *Bellerophon perturbatus* in dark slates near Bangor, and also other fossils in the slates, identical with those of the Llandeilo rocks, "which overlie the Arenig porphyries." It is doubtful if the black slates of Anglesey are the equivalents of the dark earthy slates that range east of the Arenig mountain. The Anglesey slates contain *Asaphus Powisii* and *Phacops apiculatus*, both rare in the Llandeilo group; but the *Asaphus* occurs both in North and South Wales, *Phacops apiculatus* only in Anglesey. The Graptolites, through *Climacograptus cœlatus* (?) and *Didymograptus Murchisoni*, distinctly enable us to refer the beds to the Llandeilo group.

The Llandeilo rocks and their fossils in North Wales are confined to few localities, and are but feebly exposed anywhere; and the whole fauna of this formation in that area numbers 47 species. Eighteen of these belong to the prolific class Brachiopoda, 15 to the Crustacea. The Llandeilo rocks of South Wales contain 88 species; and about 40 are common to North and South Wales. It is important to show those species which unite the two areas; but for my purpose I name only the Crustacea (Trilobita), Hydrozoa, and Brachiopoda. Of the former class 8 species are common, viz. *Asaphus tyrannus*, *A. Powisii*, *Ogygia Portlockii*, *Calymene cambrensis*, *C. Blumenbachii*, *Trinucleus concentricus*, *T. favus*, and the Ostracode *Beyrichia complicata*.

The Hydrozoa are not less important; they are *Diplograptus foliaceus*, *D. dentatus*, *Didymograptus Murchisoni*, *Leptograptus flaccidus*, *Dicranograptus ramosus*, *D. formosus*, *D. Nicholsoni*, *Climacograptus bicornis*, *C. cœlatus*, *C. confertus*, *C. Sharenbergi*, and *Dicellograptus sextans*.

The Brachiopoda number still more, as we should expect from their habit and relation to the sea-beds upon which they live. They are all common and well-known species; and 8 of the 13 forms belong to the genus *Orthis*: they are *Crania divaricata*, *Siphonotreta nucula*, *Orthis vespertilio*, *O. turgida*, *O. Actoniæ*, *O. calligramma*, *O. striatula*, *O. elegantula*, *O. insularis*, *O. bifoveata*, *Strophomena rhomboidalis*, *Leptæna tenuissimistriata*, and *L. sericea*.

Cardiola interrupta is the only Lamellibranch out of the known 6 species, and *Bellerophon perturbatus* and *B. bilobatus* the only 2 Heteropoda out of 7, which, with *Favosites fibrosus*, help to make up the 41 species connecting the North and South Wales Llandeilos; so that, of the 47 North-Wales species, 40 are common to both areas. No less than 88 species occur in South Wales. The whole Llandeilo fauna for the British Islands numbers 80 genera and 175 species; of these I may mention that Ireland has yielded 51 species, Scotland 66, and Shropshire only 26: these latter are chiefly from the Shelve district, and are mostly Crustacea and Brachiopoda. Our knowledge of the number of species occurring in Scotland is due to the researches of Mr. Lapworth in the Moffat area.

In the St.-David's area and throughout Pembrokeshire, Breconshire, and Caermarthenshire, the typical localities of Llandeilo and Builth &c. contain a special fauna. At Abereiddy Bay the black slates and argillaceous limestones are interstratified with felspathic tuff; they rest upon the Arenig group, having a distinct fauna; a thick bed of tuff divides them. The immediate presence and abundance of *Didymograptus Murchisoni* and *Dicellograptus*, *Cryptograptus*, &c. in the slates on the south side of Abereiddy Bay above the felspathic tuff, at once clearly marks or determines the base of the Llandeilo beds.

Dr. Hicks divides the true Llandeilo series of St. David's into 3 subgroups*, the lowest containing most Rhabdophora or Graptolites, associated with *Trinucleus Ramsayi*, *Calymene Murchisoniæ*, and *Theca caereesiensis*, which especially characterize this lower division. The middle subgroup consists of dark "calcareous shales, with compact limestone at the upper part;" *Asaphus tyrannus*, *A. peltastes*, *Calymene cambrensis*, *Ogygia convexa*, and *Trinucleus Lloydii* are the typical Crustacea, with *Lingula granulata*, *Halysites catenulatus*, and 6 Graptolites. In addition to the fauna, the calcareous nature of the beds lithologically separates this middle subgroup from the over- and underlying series. Everywhere it is characterized by the forms just enumerated; many of the same occur at Llandewi Velfrey, Lampeter Velfrey, and Musclewick Bay. The Upper Llandeilo is also distinguished by special forms of Trilobita —*Barrandia Cordai*, *B. longifrons*, *Cheirurus Sedgwickii*, *Ogygia Buchii*, *Calymene duplicata*, *Ampyx nudus*, and *Agnostus M'Coyii*. It will be seen that each division is specialized or can be discriminated by its Crustacea; the well-known *Ogygia Buchii* and *Cheirurus Sedgwickii*, here as elsewhere, are the typical forms in the upper black argillaceous slaty flaggy sandstones. The middle yields *Asaphus tyrannus*, *A. peltastes*, and *Ogygia convexa*, &c.; and the Lower *Calymene Murchisoniæ* and *Trinucleus Ramsayi*; and this grouping holds good wherever the Llandeilo beds occur. Three

* Quart. Journ. Geol. Soc. vol. xxxi. pp. 177–180.

species only of Trilobita have occurred in the Scotch Llandeilo rocks, viz. *Illænus Bowmannii*, *Salteria involuta*, and *S. primæva*. Ireland has 5; but probably many more will occur. I enumerate them so far as we know them—*Acidaspis Jamesii*, *Ampyx mammillatus*, *Ogygia Portlockii*, *Phacops truncato-caudatus*, and *Æglina mirabilis*. I know no others, although in all the three Llandeilos we have 45 species of Crustacea. Shropshire has only yielded 11 species, and these chiefly from the Llandeilo rocks of Shelve: they are all marked species. In the Builth and Llandeilo areas no species occurs below the tuff-beds of the Lower Llandeilo. Few species of Graptolites are common to the Llandeilo and Arenig rocks of St. David's, although here the succession is so complete, and no less than 18 species there occur in the Arenig and 6 in the Llandeilo. Only 16 species of all groups are common to both formations, although the Arenig fauna numbers 149 and the Llandeilo 175, thus clearly showing the faunal differences.

Llandeilo beds are known in Merionethshire, Caernarvonshire, Denbighshire, and Anglesey. Fifteen species have been determined from Merioneth; 13 from Garn, east of Arenig, by far the largest fauna in North Wales. Anglesey from five localities yields 15 species and 18 occurrences, or only 3 species for each locality; Caernarvonshire, from four localities, 17 species (the chief locality, Teddyn-Dicum, has produced 8 species); and Craig-y-Glyn, near Llanrhyader in Denbighshire, 6 species. No one can doubt, from the above results, that careful research would greatly add to the faunal value of the Llandeilo rocks of North Wales. Prof. Hughes has lately succeeded in ascertaining the presence of Tremadoc fossils in Anglesey; and further search at Garn, east of the Arenigs, could not fail to throw much light upon both the Arenig and Llandeilo faunas, and to substantiate still more the relation between North and South Wales. As yet, out of 13 Garn fossils, we know only 1 Trilobite (*Ampyx mammillatus*). In Anglesey, near Llanerch-y-medd, out of 5 species collected 3 are characteristic Trilobites—*Phacops apiculatus*, *Asaphus Powisii*, and *Calymene cambrensis*. It is the same with Treiorwerth in Anglesey,—clearly showing that a rich harvest of Llandeilo species is yet to be obtained in North Wales.

The elaborate researches of Mr. Lapworth, in Scotland*, into the history of the Rhabdophora of that and other areas, has greatly modified our views respecting their distribution and range.

The oldest fossiliferous strata known in Scotland are the Graptolite shales forming the well-known Moffat series, a group of black shales about 600 feet in thickness, and separated by Mr. Lapworth into three distinct palæontological divisions. The lowest (Lower Moffat or Glenkiln Shales) he determines to be of Upper-Llandeilo age; the Middle Moffat or Hartfell Shales above he correlates with the Bala group of North Wales "as an attenuated representative;" and the third or uppermost (the Upper Moffat or Birkhill Shales) represents the Lower Llandovery. This last determination has an

* Quart. Journ. Geol. Soc. vol. xxxiv. pp. 240–346.

important bearing upon the distribution of the Graptolithina or Rhabdophora, it being well known that in the Llandovery rocks of Wales no Graptolites occur. The Lower Llandovery of Cardigan and Merioneth, of such great thickness and extent (yet without Graptolites), has "dwindled down to the thickness of the Birkhill Shales (about 70 feet) in the intervening Lake-district, where it constitutes the Coniston Mudstones—a group of beds almost identical in thickness, lithology, and palæontology with the equivalent Scottish deposit of the Birkhill Shales" (*Lapworth*). The conclusion arrived at by Mr. Lapworth, that the oldest beds of the south of Scotland (the Glenkiln Shales) are the equivalents of the highest Llandeilo rocks, is borne out through his researches amongst the Moffat series in Southern Scotland; and, with him, we must come "to the conclusion that the Lower Silurian rocks of the southern uplands can be arranged in two distinct formations, viz. a lower and very thin group of fine-grained Graptolite shales, and an upper and comparatively massive series of arenaceous strata. In their mineralogical features and palæontological characteristics the Moffat series differ from any of the typical Silurian rocks of the principality." Unlike the rocks of Wales, they are almost exclusively Graptolitic in their fossil contents, scarcely any Brachiopoda or Crustacea being known throughout the series. The Llandeilo age of the Lower Moffat shales is further determined through the total absence of those complex Arenig forms of "*Dichograpti*, *Tetragrapti*, and *Phyllograpti*, so characteristic a feature of the Graptolitic fauna of the Skiddaw, Shelve, St. David's, and Canadian equivalents."

Mr. Lapworth, "arranging the Moffat strata in the order in which they are displayed, and distinguishing each chief band by its peculiar fossil," gives the following Table:—

III. Birkhill Shales.	Upper Birkhill or Grey Shale group.	Zone of *Rastrites peregrinus*.	Lower Llandovery.
		Zone of *Monograptus spinigerus*.	
		Subzone of *Diplograptus cometa*.	
	Lower Birkhill or Black Shale group.	Zone of *Monograptus gregarius*.	
		Zone of *Diplograptus vesiculosus*.	
		Zone of *Diplograptus acuminatus*.	
II. Hartfell Shales.	Upper Hartfell or Barren Mudstone group.	Zone of *Dicellograptus anceps*.	Bala.
		Zone of Barren Mudstones.	
	Lower Hartfell or Black Shale group.	Zone of *Pleurograptus linearis*.	
		Zone of *Dicranograptus Clingani*.	
		Zone of *Climacograptus Wilsoni*.	
I. Glenkiln Shales.	Upper Glenkiln Shales.	*Didymograptus* beds.	Upper Llandeilo.
	Lower Glenkiln Shales.	Ribbed mudstones.	

The facies of the Glenkiln shales is distinctively that of the Llandeilo of South and North Wales, the assemblage being the same: differences occur dependent upon locality and the mineral composition of the beds; but the common Glenkiln forms of Scotland, and those species collected by observers in North Wales (Messrs. Salter, Hopkinson, Homfray, Gibbs, &c.), serve at once to connect and correlate the faunas of the two areas. 10 species from South Wales and 12 from North Wales are all Glenkiln species and of Llandeilo age;

and, adopting the views of Mr. Lapworth, from the absence of *Didymograptus Murchisoni* and the genus *Phyllograptus* in the black shales of the Tremadoc area, and the presence of some succeeding Bala forms, we may infer that these dark Tremadoc shales and the Glenkiln beds are probably of higher-Llandeilo age. This inference is further strengthened by researches made by Linnarsson in the Llandeilo strata "of Central Sweden, where the greater portion of the Llandeilo formation of Britain is represented by the *Orthoceras*-limestone." "Upon this limestone rests the sheet of dark shales named by Dr. Linnarsson the 'Middle Graptolite schists;' the lowest part of these schists, according to Dr. Tornquist, affords abundant examples of *Phyllograptus* and the *Murchisoni* form of *Didymograptus*. The highest Swedish beds assigned or referable to the Llandeilo formation afford both the peculiar Scotch or Glenkiln and North-Wales forms, such as *Didymograptus superstes*, Lapw., *Cœnograptus gracilis*, Hall, *Climacograptus Scharenbergi*, Lapw., *C. perexcavatus*, Lapw.

Mr. Lapworth further discusses the relations and affinities of the Llandeilo species of South Scotland (Glenkiln Shales) with the dark shales and flagstones of the Cincinnati group which bound the valley of the Hudson near the city of Albany and everywhere underlie the Trenton limestone; he shows reason for believing that we may regard them as forming the "highest division of the Quebec group (Arenig) which emerges unconformably from below the horizontal Trenton limestones. The Hudson-River shales may therefore represent the higher Llandeilo beds of Britain." Lapworth names 14 species collected from Norman's Kiln in the valley of the Hudson, on the Marsouin river, &c., as being identical with the Glenkiln and Welsh forms. He still further establishes representative affinity between the peculiar Glenkiln species which are absent from the American strata and others which occur in them. Thus:—

British.		American.
Glossograptus Hincksii	is represented by	*Glossograptus ciliatus*, Emm.
Dicranograptus ziczac	,, ,,	*Dicranograptus furcatus*, Hall.
Climacograptus Scharenbergi	,, ,,	*Climacograptus scalaris*, His.
Clathrograptus cuneiformis	,, ,,	*Clathrograptus Geinitzianus*, Hall.

"All evidence, therefore, tends to prove that the Glenkiln shales belong to the age of the Upper Llandeilo series, and are closely allied to the North-Wales grouping." From the absence of certain *Didymograpti* and *Phyllograpti* from the Glenkiln division, and their abundance in the lower beds of the Llandeilo of Wales and Sweden, we are obliged to assign the Scotch Glenkiln Rhabdophora "to the highest division of the Llandeilo, and not far below the base of the Caradoc or Bala"*.

It is of the Hydrozoa, Crustacea, and Brachiopoda, which together make up the 123 out of the 175 known species, that the mass of the fauna of the Llandeilo is composed. The same classes largely transmit their genera and species to the succeeding Caradoc or Bala

* For an exhaustive paper upon the Graptolites of the Moffat series, by C. Lapworth, Esq., F.G.S., see Quart. Journ. Geol. Soc. vol. xxxiv. pp. 240–343. The general characters of the Lower Silurian rocks of Scotland and the strata of the Moffat district are also ably discussed.

rocks, viz. 16 species of Hydrozoa, 17 Crustacea, and 23 Brachiopoda, or, together, 56 out of the whole 76 that connect the two formations. It is interesting to know also those areas that are specifically most prolific in the above groups, and thus help us to draw conclusions as to the nature of the sea and its bathymetrical condition during the time of the deposition of the Llandeilo and succeeding Caradoc, which are more intimately related than is generally believed. United, the Llandeilo fauna of North and South Wales is constituted by 94 species; or this is the known number for Wales, 88 occurring in South and 47 in North Wales, and 41 being common to both, chiefly among the Hydrozoa and Crustacea. Upon whatever hypothesis we may account for the physical relationship between the Llandeilo rocks of Scotland and Ireland, the connecting species are few (only 27); and no Crustacea are common to these two countries—which, out of a total fauna of 45 species, is remarkable. The Irish species number 6, 3 of which are also South-Wales forms—*Ogygia Portlockii*, *Calymene duplicata*, and *Æglina mirabilis*. As before stated, Scotland has hitherto yielded only 4 genera and 5 species of Crustacea—*Illænus Bowmanii*, *Salteria involuta*, *S. primæva*, *Peltocaris aptychoides*, and *Discinocaris Browniana*.

Plantæ.—None.

Protozoa.—*Ischadites antiquus*, Salt. No other Protozoon has been recognized in the Llandeilo; it is not a common genus in the Lower Silurian rocks.

Hydrozoa.—The Llandeilo beds of Scotland appear to be the most prolific in Rhabdophora. Our knowledge of them is due to the researches of Nicholson, Lapworth, and Carruthers in Scotland, all of whom have done able work in elucidating the history and structure of this obscure class. Forty-four species illustrate 18 genera; but it is chiefly through the larger genera that this Graptolitic fauna is represented. South Wales, as we should expect, is also representative, although poor, as compared with Scotland, having only 18 species, or about half the number. North Wales has 7 species, and Ireland 28. The Welsh and Irish genera have not the same specific value; generally they are much the same, but illustrated by fewer species. This may be due to want of systematic search in Wales, such as the rocks of Scotland have undergone by the above-mentioned authors. The genera *Didymograptus*, *Diplograptus*, *Climacograptus*, and *Dicellograptus* are those chiefly occurring in South Wales; and *Diplograptus*, *Dicellograptus*, and *Climacograptus* in North Wales, &c. The Llandeilo rocks of Ireland contain species of nearly all the above genera. Thus of the 44 known Llandeilo Rhabdophora we have

	Species.
South Wales	18
North Wales	7
Scotland	32
Ireland	28
	85 occurrences;

and 16 species pass to the succeeding Caradoc.

ACTINOZOA.—*Halysites catenulatus*, Linn., *Favosites fibrosus*, Goldf., and *Monticulipora favulosa*, Phill., *complete the list* of the Llandeilo Actinozoa. No English form is known. North Wales yields *Favosites fibrosus*. All three occur in South Wales, and *Favosites fibrosus* in Ireland. Scotland has no representative. All three species pass to the Caradoc. These are the *first corals* occurring in the British rocks; but they expand to 20 genera and 42 species in the succeeding Caradoc. We cannot admit that change of condition only thus favoured the growth and development of the Actinozoa. It is true little limestone occurs in the Llandeilo, and that little in the upper division; but the organic remains in the Upper Llàndeilo limestones are chiefly Crustacea. The increase of limestones and calcareous matter in the Caradoc rocks being due to life agency, we may attribute much of it to the secretion of carbonate of lime by the Cœlenterata. The only notable or appreciable form is *Halysites*, which was abundant.

ECHINODERMATA.—We know of only 4 genera and 4 species of this class, which, like the Actinozoa, may be said to first appear in the Llandeilo. None are known in the Arenig below; but 4 species (1 Menevian and 3 Tremadoc) in fragments have been preserved in older formations. The 4 Llandeilo species are *Actinocrinus Wynnei*, *Echinosphærites granulatus*, *Palæasterina Kinahani*, and *Glyptocrinus basalis*. The first 3 are Irish; *Glyptocrinus* occurs in the South-Wales Llandeilos. Two of them passed to the Caradoc. As with the Actinozoa, this group became greatly developed in the Caradoc, no less than 15 genera and 32 species enriching that formation. These, like the corals, must have lived in a moderately deep sea well charged with calcareous matter.

ANNELIDA.—It is questionable if more than 6 species (although 9 are placed in the Llandeilo) occur: *Palæochorda teres*, *P. major*, and *P. minor* may be Arenig; they are very sparingly distributed, only 1 species occurring in England, South Wales, and North Wales, and 2 in Scotland. I know of no Irish Llandeilo Annelida.

CRUSTACEA.—In this class the Trilobita are of high significance, in both the Llandeilo and Caradoc formations, especially the latter, in which we know of more than 100 British species. The Llandeilo rocks have yielded 18 or 20 genera and only 45 species, or upon the average only about 2 species to each genus. Many genera are represented only by 1 species; these are *Homalonotus* (*H. bisulcatus*, Salt.), *Lichas* (*L. patriarchus*, W.-Edg.), *Stygina* (*S. Murchisoniæ*, Murch.), *Cheirurus* (*C. Sedgwickii*, M'Coy), and *Acidaspis* (*A. Jamesii*, Salt.). Much has yet to be done by collectors to increase our knowledge of the specific crustacean fauna of the Llandeilo rocks. South Wales being the classical locality for the Llandeilo group, it is natural that we should expect to find there the largest and most typical fauna, crustacean or otherwise. In one group (Graptolites) we have seen that this is not the case, Scotland being most representative. Here, however, the Crustacea of South Wales (29 species) are double those of North Wales (15), and ten times more than those of Scotland, which has yielded only 3 species, conditions being more favourable for the support and distribution of certain forms of life in one area than the other. The only 3 Scotch Llandeilo species known to me are *Illænus Bowmanii*, Salt., *Salteria involuta*, Thom., and *S. primæva*, Thom. The 6 Irish species are *Acidaspis Jamesii*, *Ampyx mammillatus*, *Ogygia Portlockii*, *Phacops truncato-caudatus*, *Calymene duplicata*, and *Æglina mirabilis*. The English forms are chiefly from the Shelve area; and 8 out of the 10 are South-Wales species.

The following occupy and characterize definite areas; they are single representatives of the genera named:—

	North Wales.	South Wales.	England.	Scotland.	Ireland.
Homalonotus bisulcatus......	*				
Agnostus M'Coyi	...	*			
Stygina Murchisonæ	...	*			
Cheirurus Sedgwickii	...	*			
Acidaspis Jamesii	...	...	...	...	*
Lichas patriarchus	...	*			
	1	4	...	...	1

Thus 6 Llandeilo genera are illustrated by only 1 species each, England and Scotland having no really marked or characteristic form. Nevertheless there are important Llandeilo species which are entirely restricted to that formation, not ranging either lower or higher. The most important are:—

	North Wales.	South Wales.	England.	Scotland.	Ireland.
Illænus Murchisoni	...	*			
Ogygia angustissima	...	*			
—— Portlockii	*	*	...	...	*
—— corndensis	*	...	*		
—— Buchii	*	...	*		
—— convexa	*	...	*		
Asaphus tyrannus	*	*	*		
—— peltastes	...	*			
—— laticostatus................	...	*			
Calymene cambrensis	*	*	*		
Trinucleus Lloydii	...	*	*		
—— Ramsayi..................	...	*			
—— Edgelli	*				
—— favus	*	*			
Salteria involuta	...	...	...	*	
—— primæva..................	...	...	...	*	
Barrandia longifrons	...	*			
—— radians	...	*			
—— Cordai.....................	...	*			
Æglina major	*				
	9	13	6	2	1

All the above 20 species are confined to the Llandeilo and to the geographical areas assigned to them, and they are essentially characteristic; the remaining 15 species pass to the Caradoc, and are therefore of no value stratigraphically. To complete the analysis of the distribution and value of the Crustacea I name the 15 species that connect the Llandeilo and Bala formations:—

Acidaspis Jamesii.	Calymene Blumenbachii.
Homalonotus bisulcatus.	—— brevicapitata.
Illænus Bowmanni.	Trinucleus fimbriatus.
Ampyx mammillatus.	—— concentricus.
—— rostratus.	Phacops apiculatus.
—— nudus.	—— truncato-caudatus.
Asaphus Powisii.	Æglina mirabilis.
Calymene duplicata.	

The singular Phyllopod *Peltocaris aptychoides* occurs both in Scotland and North Wales, and is not known out of the Llandeilo beds.

Brachiopoda.—This class is an important factor in the Llandeilo rocks; 10 genera and 34 species are known. Five new genera appear, *Acrotreta*, *Crania*, *Rhynchonella*, *Strophomena*, and *Leptæna*; the first 4 with a single known species only; but *Leptæna* has yielded 4 species, all of which occur in South Wales, and 2 of them in North Wales. As we should anticipate, the species are most numerous in South and North Wales. The former area gives us 26 species, the latter 18; Scotland 9, and England 6. Although there are 20 species in the Arenig group (and 34 in the Llandeilo) *yet no species is common to the two formations*, no Arenig form passes up; but of the 34 Llandeilo forms, 23 pass to the Caradoc. This is chiefly through the genera *Lingula*, *Orthis*, and *Leptæna*—4 out of 6 in the former genus, 11 out of 13 in *Orthis*, and all the known 4 in *Leptæna*. We have already seen that of the whole fauna of the Arenig (150 species) only 17 pass up into the Llandeilo; whereas no less than 72 out of 175 Llandeilo species are found in the Caradoc, viz. Hydrozoa 16 species, Crustacea 17, Brachiopoda 23, Bivalvia 3, Gasteropoda 4, Heteropoda 5, and Cephalopoda 2. The *remaining forms* are distributed through smaller classes. But for the distinctive character of the Abereiddy-Bay and Caermarthenshire faunas, there is much that is common between the Llandeilo and Caradoc.

Lamellibranchiata.—With the exception of the Irish species *Pleurorhynchus calcis*, Baily, all the Bivalve Mollusca known are from the South-Wales Llandeilos. We know of no Llandeilo Pelecypod mollusk either in England or Scotland. *Cardiola interrupta* occurs in both North and South Wales; *Modiolopsis expansa*, *M. inflata*, *Ctenodonta varicosa*, and *Palæarca amygdalus* only in the South-Welsh beds. Three pass to the Caradoc. *Pleurorhynchus* and *Cardiola* are new genera.

Gasteropoda.—South Wales has hitherto only given us 1 species, *Murchisonia simplex*, M'Coy; Ireland 2, *Euomphalus parvus*, Portl., and *Turbo tritorquatus*, M'Coy; the Shelve area and North Wales *Cyclonema crebristria*, M'Coy, and *Euomphalus corndensis*, Sow., the remaining 7 being from the Durness limestone of Scotland (they may be Arenig). The Scotch species are *Euomphalus matutinus*, Hall, *Murchisonia angulocincta*, Salt., *M. angustata*, Hall, *M. bellicincta*, Salt., *M. gracilis*, Hall, *Ophileta compacta*, Salt., and *Pleurotomaria thuli*, Salt. Three of the 12 pass to the Carodoc. *Euomphalus*, *Cyclonema*, and *Murchisonia* are new genera, and first appear in the Llandeilo.

Pteropoda.—Three species of *Theca*—*T. cometoides*, Baily (Irish), *T. reversa*, Salt., and *T. caereesiensis*, Hicks (from St. David's). No species occurs in England, North Wales, or Scotland.

Heteropoda.—Scotland possesses 5 of the 7 species known; and 4 of the 5 are *Maclureæ*. These are associated with the Gasteropoda in the Durness limestone. *Bellerophon perturbatus* is a North and South Welsh species; and *B. bilobatus*, English, North and South Welsh also. *Euomphalus scoticus* is from the Ayrshire rocks. The 3 last-named species and *Ecculiomphalus* pass to the Caradoc.

Cephalopoda.—Of the 3 genera and 7 species none occurs either in North Wales or Ireland. The only English species is *Orthoceras Avelani*?, Salt., from the Shelve area (Shropshire); *Endoceras eoum*, Edgell, is from South Wales. The remaining 5 of the 7 known species are Scotch, including the singular genus *Piloceras* (*P. invaginatum*) from the Durness limestone.

The accompanying Table (p. 126) gives the following results. The 12 zoological groups occurring in the Llandeilo rocks are represented by 80 genera and 175 species, which are numerically distributed as follows:—

England	18	genera	and	26	species.
North Wales..	30	,,	,,	47	,,
South Wales..	47	,,	,,	88	,,
Scotland	31	,,	,,	66	,,
Ireland	31	,,	,,	57	,,

38 genera and 73 species of the 175 pass to the Caradoc. It will be seen that it is through the Hydrozoa, Crustacea, and Brachiopoda that the community of species largely occurs between the Llandeilo and Caradoc generically and specifically—through the Hydrozoa 9 genera and 16 species, the Crustacea 9 genera and 17 species, and the Brachiopoda 7 genera and 23 species. The remaining passage numbers are seen in Table IX.

Table IX.—*Llandeilo.*

From Arenig.	Classes.	Genera.	Species.	Geographical Distribution. England.	North Wales.	South Wales.	Scotland.	Ireland.	Pass to Caradoc.
	Plantæ.								
	Protozoa	1	1	...	$\frac{1}{1}$				
$\frac{4}{4}$	Hydrozoa	18	44	$\frac{4}{4}$	$\frac{5}{7}$	$\frac{14}{18}$	$\frac{13}{32}$	$\frac{14}{28}$	$\frac{9}{16}$
	Actinozoa	3	3	...	$\frac{1}{1}$	$\frac{3}{3}$	...	$\frac{1}{1}$	$\frac{3}{3}$
	Echinodermata	4	4	$\frac{1}{1}$	?	$\frac{1}{1}$	...	$\frac{1}{2}$	$\frac{2}{2}$
	Annelida	6	9	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{2}{2}$		
$\frac{2}{2}$	Crustacea	20	45	$\frac{6}{10}$	$\frac{10}{15}$	$\frac{12}{29}$	$\frac{4}{5}$	$\frac{6}{6}$	$\frac{9}{17}$
	Bryozoa.								
$\frac{2}{3}$	Brachiopoda	10	34	$\frac{2}{6}$	$\frac{6}{18}$	$\frac{8}{25}$	$\frac{4}{9}$	$\frac{4}{9}$	$\frac{7}{23}$
	Lamellibranchiata..	5	6	...	$\frac{1}{1}$	$\frac{4}{4}$	...	$\frac{1}{1}$	$\frac{2}{3}$
	Gasteropoda	6	12	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{4}{7}$	$\frac{2}{2}$	$\frac{2}{3}$
	Pteropoda	1	3	...	...	$\frac{1}{2}$	...	$\frac{1}{1}$	$\frac{1}{1}$
	Heteropoda	3	7	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{5}$	$\frac{1}{1}$	$\frac{2}{4}$
	Cephalopoda	3	7	$\frac{1}{1}$	...	$\frac{1}{1}$	$\frac{2}{6}$	...	$\frac{1}{1}$
$\frac{8}{9}$	....	80	175	$\frac{18}{26}$	$\frac{27}{47}$	$\frac{47}{87}$	$\frac{31}{66}$	$\frac{31}{51}$	$\frac{38}{73}$

Caradoc or Bala.

The rocks overlying the Arenig and Llandeilo groups, and underlying the May-Hill Sandstone, have received much critical attention from Sedgwick, Murchison, M'Coy, Salter, and the officers of the Geological Survey. The facies of the fauna is that of the Llandeilo, but greatly developed. The increased fauna of the Caradoc is scarcely recognized until subjected to critical research and analysis. The difference in the fossil contents of the two groups is due chiefly to age and the conditions under which they were deposited. Sedgwick, in 1853, placed the Bala group in his "Upper Cambrian" division, dividing it into Lower, Middle, and Upper Bala; it includes also the Cambro-Silurian of some authors, a term used or adopted by Prof. Jukes in his 'Manual of Geology.'

From the year 1832 to 1853 Sedgwick included the Caradoc in the term "Lower Bala," not admitting then the existence of the term Caradoc. Sir H. de la Beche, Prof. J. Phillips, and the Survey, from 1840 to the present date, designate this formation the "Caradoc or Bala." Murchison, from 1831 to 1859, used the term "Caradoc

Sandstone." The term Llandeilo was not admitted by Sedgwick either in the 'Synopsis' or the Woodwardian Catalogue; therefore great difficulty was and is still felt as to the identification of species long ago collected in certain localities, especially those having reference to the Lower "Llandeilo of Murchison" and the Arenig of Sedgwick; the faunas of all three groups require careful revision, in consequence of old or early errors, which of necessity demand it.

Sir Roderick Murchison, in 1833, first noticed the "Caradoc Sandstone"*; in 1834 the same rocks were described by him under the name of the "Horderley and May-Hill Sandstone." In the 'Silurian System,' subsequently published, these strata were called "Caradoc Sandstone," the name being based upon their being highly developed in the neighbourhood of Caer Caradoc.

In the early history of the Caradoc rocks the fossils of the *Pentamerus*-beds were included in its lists. The Survey subsequently corrected this, by separating the upper part or highest beds of the Caradoc. In 1852 Prof. Sedgwick and Mr. Salter in part corrected this error, and showed that the fossils of the May-Hill group were very distinct from those of the Caradoc Sandstone. Again, the upper *Pentamerus*-beds rest unconformably on the true Caradoc Sandstone, and the whole pass under the Wenlock Shale. In Shropshire and at Builth the unconformity is visible; and in the Malvern area, west of the Herefordshire and Worcestershire Beacons, the Upper Llandovery beds lie directly upon the Upper Lingula-flags or "*Dictyonema*-shales." Again, the Upper Llandovery beds on the banks of the Onny river lie on the upper part of the Caradoc or Bala beds. West of Wenlock Edge they cover the nearly vertical edge of the Cambrian or Longmynd rocks. "Probably," says Prof. Ramsay, "there is no unconformity so complete yet observed in other members of the British Silurian strata." Besides the researches and large collections of fossils made by the Survey from these rocks, the labours of Sedgwick are preeminently associated with the Caradoc and Bala beds of Wales, through the great memoir on the British Palæozoic Fossils, in which he was so well aided by Prof. M'Coy, and the "Woodwardian Catalogue"† prepared by Salter from the great store of materials in the Woodwardian Museum at Cambridge, and which, many years previously, he had helped Sedgwick to collect, and name, from the classical localities in Wales. To Prof. Ramsay, for his valuable memoir on the Geology of North Wales‡, every student is deeply indebted. In this great treatise every detail relative to the physical history and distribution of the Caradoc and Bala rocks and fossils is treated upon; and to the appendix, originally compiled by Mr. Salter, I have greatly added, especially in that portion treating of the distribution of life, not only for the Caradoc, but through the whole of the for-

* Proceedings of the Geological Society, 1833, vol. i. p. 476.

† 'A Catalogue of the Collection of Cambrian and Silurian Fossils contained in the Geological Museum of the University of Cambridge.' By J. W. Salter, F.G.S. With a Preface by the Rev. A. Sedgwick, LL.D., F.R.S.

‡ Mem. Geol. Surv. of Great Britain, vol. iii. Geology of North Wales.

mations of North and South Wales. The portion of the memoir by Prof. Ramsay devoted to the Caradoc is of necessity large, arising from the extent, magnitude, and importance of the Caradoc rocks as developed in North and South Wales, Westmoreland, Ireland, and Scotland. I therefore, as in the case of the older groups, compare or attempt to correlate other portions of Britain with the typical area in Wales, so as to show the present aspect or distribution of the Caradoc fauna, which is so largely developed in the British Islands. To devote much space to the purely geological aspect of the Caradoc would be needless under present circumstances, as so much has already been done by able observers in the pages of our Journal, as well as in the exhaustive memoir on North Wales by Prof. Ramsay. My tabular results in the appendix to the above memoir, relative to the distribution of the Caradoc fossils both in time and space, will, when published, embody almost all the information known. The result, however, will be referred to here, as being a complete analysis of the 600 species. It is scarcely necessary for me to discuss the views of authors as to very minute subdivisions of the Caradoc group in any given area or under any peculiar condition; such will always arise under critical examination, extended knowledge, or constant research; and large as we know the fauna to be, owing to the rocks being so extensively worked in the days of Sedgwick and Murchison, and through the long-continued labours of the Geological Survey, yet many of the zoological groups are still being added to. This is notably the case with the elaborate memoir upon the Girvan fossils by Prof. A. Nicholson and Mr. Etheridge, jun., the first volume of which, containing this addition to our knowledge of the Caradoc fauna of Scotland, is just completed and published. In this work the authors describe 41 genera and 65 species, many of which are new. Perhaps, with the exception of Mr. Lapworth's paper on the Graptolites of the Moffat series at Girvan and Glenkiln* (mostly Lower-Bala or Llandeilo forms) no more important addition to our knowledge of the Caradoc fauna has been made since M'Coy completed his great work upon the British Palæozoic fossils.

The legends attached to the published maps of the Geological Survey, and the explanation of the colours employed to designate the horizons or formations surveyed, show that no attempt was made by the Survey to divide the Caradoc rocks into subgroups, or into Lower, Middle, and Upper Caradoc or Bala; neither does Prof. Ramsay, in that part of his memoir devoted to the Caradoc rocks, attempt any subdivision, but masses the whole group between the top of the Llandeilo and the overlying Llandovery. In the Catalogue of the Cambrian and Silurian fossils in the Woodwardian Museum, Cambridge, Prof. Sedgwick has divided the Bala beds into three subgroups, placing them in his Upper Cambrian stage (the Cambro-Silurian of some authors), the Lower Silurian of Murchison. The grouping adopted in this catalogue is such as to eliminate the true Llandeilo fossils,

* Quart. Journ. Geol. Soc. vol. xxxiv. pp. 249–346.

and place them in his Lower Bala group. The Bala group, or Upper Cambrian of Sedgwick, consists therefore of

Upper Cambrian*.	Lower Bala = Llandeilo flags (Upper Llandeilo of the Geological Survey, the Arenig being the Lower). Middle Bala = the Caradoc Sandstone and Bala rocks (Geological Survey and Sir R. Murchison). Upper Bala = the Caradoc Shales, Hirnant Limestone, and Lower Llandovery rock (Geological Survey).

The Upper Llandovery or May-Hill Sandstone unconformably overlies these.

Sedgwick's Middle Bala, and part of the Upper, are therefore equivalent to the true Caradoc of the Geological Survey; and as such I treat that group here; or the Middle Bala of the Cambridge Catalogue will embrace the whole of the 600 species known as Caradoc forms. I have already discussed the Llandeilo formation proper in the sense now used by the Geological Survey, having relegated those species hitherto called Lower Llandeilo to the Arenig group—the Middle Cambrian of Sedgwick†. The Lower Bala includes certain dark earthy slates and bands of limestone occurring on the east flank of the Arenigs, Mynydd Tarw and Craig-y-glyn above Llanarmon in the Berwyns, the black slates on the flanks of Snowdon, also the arenaceous deposits on the west side of Bala Lake below the Bala Limestone, and that limestone also.

The Middle Bala group of the Woodwardian Catalogue embraces the Bala Limestone and its associated sandstones and slates in North and South Wales. In Shropshire it is the Caradoc Sandstone, with its Horderley Limestone. The Coniston and Kildare limestones, and the Craig-Head and Peebles limestones, are all of this age‡.

Sedgwick's "Upper Bala" comprehends the Aber-Hirnant beds above the Bala Limestone (with peculiar fossils), the lower part of the Coniston Flags (that conformable to the limestone), and all beds above the Bala Limestone and beneath the May-Hill Sandstone. Again, the "Upper Bala" includes all the beds, whether near Meifod or Welchpool or Llanwyddyn, which lie above the Bala Limestone and under the unconformable cover of the Denbighshire grit and flag. In ascending order the Upper Bala includes

Upper Bala (Sedgwick).	1. The Hirnant Limestone and slate = Coniston Flags, lower part only (Ashgill, Coldwell, &c.), above the Coniston Limestone. 2. Llandovery beds (Lower Llandovery of Murchison) = the Mathyrafal Limestone, near Meifod, of Sedgwick.

"It is the great fossiliferous group of Haverfordwest. The Dalquorhan and Mullock beds in Ayrshire, the fossiliferous rocks of Maume and Cong in Galway belong in part to it"§.

* *Vide* Woodwardian Catalogue, Cambridge, pp. 25, 26, &c.

† Consult the table of equivalents of the strata underlying the May-Hill Sandstone, Woodwardian Catalogue, p. 25.

‡ *Vide* Woodwardian Catalogue, pp. 26, 39. § *Loc. cit.* pp. 26, 72.

It has been stated that the fauna of the Llandeilo rocks numbers 80 genera and 175 known species. The Caradoc or Bala contains 179 genera and 613 species; or 88 new genera and 375 new species make their appearance either at the close of the Llandeilo or during that period which ushered in or brought about those changes of conditions under which the deposits of the Caradoc sea were accumulated and its species developed and multiplied, covering as it does so extensive an area in Europe and Britain, also extending to America, whether homotaxially in that region or contemporaneously with the deposition in the British area it is difficult to say. That the Trenton and Hudson-River group of North America, and nearly the whole of the Etage D of Barrande (Bohemia) and Regio D of Angelin (Sweden), are the equivalents of our great Middle Caradoc and Bala, or the true Caradoc, is now not doubted. The fauna of the Bala group, especially in its zoological groupings, differs much from the preceding Llandeilo, although many species (85) are common to the two formations.

I purpose treating of the Caradoc rocks and their fossils at some length—their stratigraphical place, the geographical distribution of their fossils (especially with reference to the succeeding Lower and Upper Llandovery)—questions which demand critical examination or analysis.

The three classes having the greatest number in common are the Hydrozoa (Rhabdophora), the Crustacea (Trilobita), and the Brachiopoda. The number of known species in the Llandeilo in each of the above classes is

Hydrozoa	44
Crustacea	45
Brachiopoda	34

In the Caradoc fauna the same three classes number, including those from the Llandeilo,

Hydrozoa	38
Crustacea	146
Brachiopoda	109

Numerically, the remaining ten classes have little value for comparison, although the Actinozoa, Echinodermata, Lamellibranchiata, and Gasteropoda are well illustrated (see Table X.). It is through the above three extensively developed groups, which are mainly moderately deep-sea forms, that the two formations are united.

The fact of 73 species out of 175 passing from the Llandeilo to the Caradoc is highly suggestive, and is confirmatory of the views of Sedgwick in uniting the Llandeilo to the Lower Bala; and the distinctiveness of the great Middle Bala is confirmed by the fact that, out of 610 species in that formation, only 102 pass to the Lower Llandovery. Therefore, on palæontological data, we may regard the Llandeilo and Caradoc as being most closely allied. The 102 transgressive Caradoc species are distributed through the following classes:—

Protozoa	1	out of	10	known.		
Hydrozoa	1	,,	36	,,		
Cœlenterata	20	,,	40	,,		
Annelida	2	,,	15	,,		
Echinodermata	2	,,	32	,,		
Crustacea	16	,,	146	,,		
Bryozoa	4	,,	21	,,	Pass to Lower Llandovery.	
Brachiopoda	33	,,	109	,,		
Lamellibranchiata	3	,,	76	,,		
Gasteropoda	10	,,	53	,,		
Pteropoda	1	,,	12	,,		
Heteropoda	1	,,	15	,,		
Cephalopoda	7	,,	47	,,		
	101	,,	612	,,		

The important zoological groups in the Caradoc are therefore the Hydrozoa, Cœlenterata, and Echinodermata—the latter especially through the Cystideans, no less than 8 genera and 23 species illustrating this rare group. The Crustacea number 146 species, of which 106 are peculiar; 20 species are from the Llandeilo and 16 pass upwards to the Lower Llandovery, leaving thus for the Caradoc and Bala beds the largest Crustacean fauna known in the Lower Palæozoic rocks. Only 4 species of Bryozoa out of the 21 appear to pass to the Lower Llandovery; and they all commence in the Caradoc: they are *Fenestella subantiqua*, d'Orb., *Ptilodictya dichotoma*, Portl., *P. costellata*, M'Coy, and *P. lanceolata*, Goldf. We should expect more species in common in this group, from the fact of their being usually a moderately deep-sea family, and less subject to vicissitude or change than littoral or sublittoral species. The Brachiopoda of the Caradoc and Bala group number 109 species, representing 16 genera; they are more numerous than in other of the Palæozoic rocks. 33 of the 109 pass to the Lower Llandovery; and we have seen that the connexion with the Llandeilo below is through 26 species, leaving, therefore, 50 as Caradoc proper. As regards geographical distribution, North-Welsh forms greatly predominate, owing probably to the larger amount of research to which the rocks of the four counties of Caernarvon, Denbighshire, Montgomeryshire, and Merioneth have been subjected. Ireland also has yielded 60 species, and Scotland 40. Their more complete distribution will be further discussed under that head.

The littoral or shallow-sea condition of the Caradoc is further illustrated by the occurrence of a large number of bivalve Mollusca. No less than 76 species are known; and of these only 3 species pass to the Lower Llandovery, viz. *Pterinœa retroflexa*, Wahl., *Orthonota sulcata*, His., and *Mytilus mytilimeris*, Conr.; and 2 of these 3 forms pass to the Ludlow and the Upper Llandovery, viz. *Pterinœa retroflexa* and *Mytilus mytilimeris*; so that 66 species of Lamellibranchata belong to the Caradoc exclusively; and, strange as it may appear, these 3 are the *only species known in the whole of the Lower Llandovery.*

The Bivalvia of the Caradoc exceed in number those of any other known formation below the Carboniferous Limestone. Careful analysis shows that the Arenig rocks contain only 6 species, the Llandeilo 6, the Caradoc 76, Lower Llandovery 3, Upper Llandovery 29, Wenlock 45, and the Ludlow 71 species; about 13 species range from the Caradoc upwards or through to the Ludlow, 7 to the Upper Llandovery, 3 to the Woolhope, 11 to the Wenlock, and 12 to the Ludlow—this of course being inclusive, as some of the same forms appear more than once in their range. It is not improbable that errors as to species occur, especially when we have to do in many instances with mere casts in these arenaceous deposits. In both the Lower and Upper Llandovery groups the fossils are badly preserved, being casts only. If the Lamellibranchs are largely represented in the Bala group, the Gasteropoda are almost equally so, by 14 genera and 53 species; 2 only (*Murchisonia simplex*, M'Coy, and *Turbo tritorquatus*, M'Coy) are common to the Llandeilo below; 10 pass to the Lower Llandovery; 9 direct to the Upper Llandovery; 7 species are common to the Caradoc, Lower Llandovery, and Upper Llandovery; they are *Cyclonema crebristria*, M'Coy, *Holopella cancellata*, Sow., *H. tenuicincta*, M'Coy, *Murchisonia cancellata*, M'Coy, *M. pulchra*, M'Coy, *Trochonema triporcatum*, M'Coy, and *Rhaphistoma lenticulare*, Sow. Only 3 species pass to the Wenlock rocks; one of these is *Holopella cancellata*, Sow. The Gasteropod fauna therefore is as significant as the Lamellibranchs, no fewer than 32 of the 53 species being confined to the Caradoc or Bala group. 16 of the 53 are peculiarly Irish forms, and 5 Scotch, leaving 21 for distribution through the North- and South-Welsh and English beds, of which 9 occur in the Caradoc of Shropshire. I have no determined species from Westmoreland; North Wales yields 26 species, South Wales only 3, viz. *Cyclonema crebristria*, *Holopella cancellata*, and *Patella saturni*, and these only in Caermarthenshire. This group, like the bivalves, indicates shallow-water conditions.

The Pteropoda (4 genera and 12 species) are, with 4 exceptions, confined to the Caradoc. *Conularia Sowerbyi* passes to the Lower Llandovery, Wenlock, and Ludlow; *Ecculiomphalus scoticus*, M'Coy, is Llandeilo and Upper Llandovery; 9 of the known species are Irish, and 3 of them Scotch; so that the Lower Llandovery is only directly allied to the Caradoc by one form (*C. Sowerbyi*) out of the 12 occurring. This is even more strongly manifested by the associated class Heteropoda, of which, as in the Pteropoda, only 1 species in 15 passes to the Lower Llandovery—*Bellerophon carinatus*, Sow., being, so far as I know, the only form in this group connecting the two formations. *Bellerophon bilobatus*, Sow., *B. perturbatus*, Sow., and *Maclurea macromphala*, M'Coy, are also Llandeilo. The Upper Llandovery has 3 in common, Woolhope 4, Wenlock 2; and 2 pass to the Ludlow. Specifically, 6 pass up, leaving 8 as belonging to the horizon. The Pteropoda, being strictly or essentially pelagic, give us little clue as to bathymetric conditions at the time of deposition. Neither do the Cephalopoda; but no single class is so preeminently Caradoc: of the 47 known species, only 1

(*Orthoceras arcuoliratum*, Hall) unites it with the Llandeilo group (and this I believe to be a doubtful species); and only 7 connect it with the Lower Llandovery, and 3 of the 7 do not range higher. The 7 species are *Lituites cornu arietis*, Sow., *Orthoceras ibex*, Sow., *O. vagans*, Salt., *O. annulatum*, Sow., *O. Barrandii*, Salt., *O. politum*, M'Coy, and *O. tenuistriatum*, Münst. The 3 species that directly unite the Caradoc and Lower Llandovery are three of the above—*O. vagans*, Salt., *O. annulatum*, Sow., and *O. Barrandii*, Salt. 9 range to the Upper Llandovery, 4 to the Woolhope, 9 to the Wenlock, and 3 to the Ludlow. These are the appearances of species that ascend through and into the higher formations. 30 of the 47 species are confined to the Caradoc, not ranging higher, whereas 15 species pass to the rocks above. Ireland is represented by 24 of the 47 species, 18 of which do not leave the Caradoc horizon, and 17 are strictly confined to the Irish deposits.

Of the Scotch Caradoc Cephalopoda we only know of 6 restricted species, viz. *Orthoceras audax*, Salt., *O. arcuoliratum*, Hall (also Llandeilo), *O. vaginatum*, Schloth., *O. politum*, M'Coy, *O. primævum*, Forbes, and *O. tenuistriatum*, Münst.; and only 15 species out of the known 47 occur in the Scotch rocks.

Geographical Distribution.

I have now to treat of the geographical distribution of the extensive series of species occurring in the Caradoc and Bala rocks, the large fauna (614 species) being an additional reason for so doing, more especially considering the widely spread area occupied by the Lower and Middle Bala groups. It would be impossible to give all the localities whence our knowledge of their distribution has been derived; but the chief in North Wales number between 30 and 40, and in South Wales about 10. The Shropshire and Westmoreland localities are less numerous, but are prolific in species.

The following 10 areas, including about 50 localities in the British Islands, have yielded the 613 species known. Their occurrences or appearances number 1555.

North Wales.	Caernarvonshire	105	species, distributed in 10 chief localities.
	Denbighshire	131	,, ,, 6 ,, ,,
	Montgomeryshire	138	,, ,, 5 ,, ,,
	Merionethshire	162	,, ,, 10 ,, ,,
South Wales.	Pembrokeshire	93	,, ,, 5 ,, ,,
	Caermarthenshire	72	,, ,, 5 ,, ,,
England.	Shropshire	123	
	Westmoreland	123	
Scotland		302	
Ireland		306	
		1555	

The actual number of species (so far as we know) occurring in North Wales is 270, in South Wales 134, in Shropshire 123, in Westmoreland 123, in Scotland 302, and in Ireland 306.

The intimate relation of the Caradoc to the succeeding Lower

Llandovery rocks obliges me to show their specific affinity, for the purpose of ascertaining the palæontological value of the Lower Llandovery (the Upper Bala of Sedgwick). Analysis shows that, of the 613 Caradoc species, 103 pass to the Lower Llandovery ; but, strange as it may appear, 107 are common to the Caradoc and Upper Llandovery, although we know of the stratigraphical break that occurs between the two formations. This relation is chiefly through the Actinozoa, Hydrozoa, and Brachiopoda, as we might expect from their bathymetrical position and habitat.

Of the 40 known corals, 22 (or more than one half) range to the Llandovery rocks, 20 occurring in the Lower and 17 in the Upper Llandovery ; or all but 3 are both Lower and Upper Llandovery ; and 37 species of Brachiopoda, out of the 109 known, pass to the Llandovery, 33 of which are Lower Llandovery.

Of the 16 species of Annelida, only 2 pass to the Lower and Upper Llandovery, *Tentaculites anglicus* and *Cornulites serpularius* ; they range also to the Ludlow.

The class Echinodermata, represented by 32 species, is remarkable for the occurrence of 8 genera of Cystidea and no less than 23 species. They essentially characterize the Caradoc and Bala rocks ; with the exception of one species (*Echinosphærites arachnoidea*, Forbes), which passes up into the Lower Llandovery, all are peculiar. It is only in the Caradoc and Wenlock strata that the Cystidea are a well-developed and characteristic group of the Echinodermata ; they are replaced in the Carboniferous rocks by the Blastoidea (*Pentremites* and *Codonaster*) and do not appear again.

The Crustacea are the largest and most important class in the Caradoc. The species number 146, representing 37 genera—Ireland yielding 90 (the largest number of species), Scotland 78, North Wales 50, and South Wales 30 ; or taking North and South Wales as one area, it has 59 species, 16 genera and 21 species being common to North and South Wales. Shropshire and Westmoreland are nearly equal, the former having a known crustacean fauna of 31 species and the latter 35. The genera most largely represented are *Calymene* 8 species, *Phacops* 14, *Illænus* 13, *Remopleurides* 8, *Lichas* 6, *Staurocephalus* 4, *Acidaspis* 8, *Ampyx* 6, *Asaphus* 6, *Cheirurus* 6, and *Trinucleus* 5. The remaining 26 genera (many of which are Phyllopods) are represented by one or few species. The 37 genera of Crustacea appear or occur 217 times in the geographical areas named in the table of distribution and the horizons they pass to above, and the species appear 433 times. This Table clearly shows us how much has yet to be done before we can obtain reliable zoological data, or be assured that the several classes and genera have been even yet fairly illustrated, feeling at the same time that, except by exhaustive and careful collecting, we never shall arrive at even a fair illustration of the fauna of any given group. For example, the 9 genera of Caradoc Protozoa are represented by only 10 species, or a fraction more than 1 species for each genus. 8 of these genera belong to the Spongida ; and only among these do any 4 of the genera, illustrated by 1 species each, occur in any one locality, as in Shropshire, Scotland, and Ireland. North and South Wales have yielded only 2 genera, each with 2 species, in any of the six counties. The Actinozoa even afford us stronger evidence still of the importance of specific evidence. In this class we know through the fullest research that 20 genera and 40 species occur, thus averaging *only 2 species* for each genus. Many genera (13) have as yet yielded only 1 species; they are *Plasmopora*, *Syringophyllum*, *Halysites*, *Stylarœa*, *Omphyma*, *Thecostegites*, *Alveolites*, *Aulacophyllum*, *Calostylis*, *Cyathophyllum*, *Fistulipora*, *Tredadium*, and *Prosopora*. We cannot suppose for one moment that these genera are not represented by more species; it is a matter of research only. The genus *Favosites* has 8 species, *Heliolites* 6, *Petraia* 6, and *Monticulipora* 4. The 20 genera make 90 appearances through the 10 areas, and the species 188; 32 of the generic and 68 of the specific appearances occur in the formations above the Caradoc, and show the relation of one group of strata to another, as determined through palæontological research. The Lower Llandovery, which succeeds or is the natural termination of the Caradoc, contains 9 genera and 20 species of the whole fauna $(\frac{20}{40})$; and the Upper Llandovery 6 genera and 17 species of the whole. The coral fauna of the Caradoc at once makes its appearance underived, the older Llandeilo possessing only 3 species of Actinozoa, *Halysites catenularius*, *Favosites fibrosus*, and *Monticulipora frondosa*; whereas, next to the Wenlock, the Caradoc possesses the largest Cœlenterate fauna of the Lower Palæozoic rocks. Nowhere, either in Europe or America, does this class appear with so large a generic grouping. 20 of the 40 species pass to the Lower Llandovery; most of the same appear in the overlying and unconformable Upper Llandovery.

The Crustacea pre-eminently characterize the Caradoc and Bala rocks, and constitute the largest group in the whole of the Palæozoic series; 37 genera and 146 species have been collected, described, and registered through the labours of the Geological Survey of the three countries, England, Ireland, and Scotland, as well as by the researches of Sedgwick, Salter, M'Coy, Baily, Sharpe, Prof. Hughes, &c. No zoological group is better understood, none more important to the student of stratigraphical geology. The Lower, Middle, and Upper Bala beds could with difficulty be read or understood without a minute acquaintance with the Trilobita of this vast middle series of Lower Palæozoic deposits. They are to this group of rocks what the Ammonitidæ and Echinidæ are to the Mesozoic series. The order Trilobita is illustrated by 27 genera, the remaining 10 are mostly Ostracoda; among them is *Turrilepas*.

North Wales.	Caernarvonshire	has yielded	11	genera and	17	species.
	Denbighshire	,,	17	,,	33	,,
	Montgomeryshire	,,	13	,,	29	,,
	Merionethshire	,,	16	,,	36	,,
South Wales.	Pembrokeshire	,,	16	,,	24	,,
	Caermarthenshire	,,	13	,,	20	,,

England.	Shropshire	has yielded	15 genera	and 31	species.
	Westmoreland	,,	18 ,,	38	,,
Scotland		,,	31 ,,	78	,,
Ireland		,,	31 ,,	90	,,

The most important genera, or those of chief stratigraphical value and in which the species are numerous, are *Acidaspis* (8 species), *Ampyx* (6), *Agnostus* (5), *Asaphus* (6), *Calymene* (8), *Cheirurus* (6), *Homalonotus* (4), *Illænus* (13), *Lichas* 6, *Phacops* (13), and *Remopleurides* (8). The genera *essentially* characterizing the Caradoc are *Harpes*, *Salteria*, *Remopleurides*, *Cyclopyge*, *Dionide*, *Tiresias*, and *Cyphoniscus*, most of which are only represented by one or few forms. Scotland and Ireland possess the richest assemblage of species; 26 genera and 63 species occur in the former, and 23 genera and 77 species in the latter area. Only 15 of the 123 species of Trilobita pass to the Lower Llandovery; they are *Acidaspis Brightii*, *Calymene Blumenbachii*, *C. brevicapitata*, *C. caractaci*, *C. Allportiana*, *Cheirurus bimucronatus*, *C. clavifrons*, *Encrinurus punctatus*, *Cyphaspis megalops*, *Cybele verrucosa*, *Illænus Rosenbergii*, *I. Bowmanni*, *I. Thomsoni*, *Lichas laxatus*, and *Phacops Brongniarti*. 8 of these same also pass up into the Upper Llandovery, 6 to the Wenlock, and 5 to the Ludlow. The long-ranged species are chiefly those illustrating the largest genera, such as *Calymene Blumenbachii*, *C. Allportiana*, *Cheirurus bimucronatus*, *Encrinurus punctatus*, *Cyphaspis megalops*, and *Phacops caudatus*, all of which species appear in the Ludlow and then cease to exist, the Devonian rocks having none in common; yet *Bronteus* and *Harpes* are repeated from the Caradoc in the Middle Devonian, both in Britain and on the continent. We must remember, however, that the marine Devonian nowhere visibly overlies the Silurian rocks in Great Britain, and the Old Red Sandstone contains no true marine form anywhere.

The order Ostracoda, illustrated by *Beyrichia*, *Leperditia*, *Cythere*, *Primitia*, and *Entomis*, needs little more than notice here; they have received at the hands of Professor Rupert Jones the closest scrutiny both zoologically, palæontologically, and stratigraphically; few men have so largely added to our knowledge of the orders Ostracoda and Phyllopoda.

Brachiopoda.—And next to the Crustacea in force and classificatory value we must place this group of Mollusca or Molluscoida. Numerically in the whole of the Cambrian and Silurian rocks the Crustacea include the largest number of species, 550 being known; whilst of the Brachiopoda we know 456. Individually no class surpasses the Brachiopoda through all the Palæozoic and Mesozoic rocks, many genera being, however, far more richly represented than others. In the Caradoc this is notably the case. The genus *Orthis* has in Britain alone, we know, through the large collections that have been made and the elaborate researches of Davidson, no less than 110 species, and culminates in the Caradoc. In tracing the numerical and stratigraphical value of the genus, we find that in the Cambrian group up to the close of the Tremadoc the genus *Orthis* possesses (so far as we know) only 4 species, viz. *Orthis Hicksii*, *O. Carausii*, *O. lenticularis*, and *O. Menapiæ*; in the Arenig 10 species, the 3 last-named forms being in common with the horizon below; in the Llandeilo 13 species, 4 of which are Arenig also, viz. *Orthis alata*, *O. calligramma*, *O. remota*, and *O. striatula*.

In the Caradoc and Bala group the species have increased to no less than 41, all having extensive geographical distribution; 7 are peculiarly Irish. In the Lower Llandovery we know of 20 species, 17 of which are Caradoc, the only 3 peculiar Lower Llandovery forms being *Orthis Bouchardi*, *O. reversa*, and *O. mullochensis*. Thus through this one genus alone we see the close alliance of the so-called Lower Llandovery (the Upper Bala of Sedgwick) with the Caradoc. The moderate depth at which they lived is clearly indicated by the coarse and varied arenaceous nature of the deposits, for there is no evidence to show, even by the zoological grouping, deep-sea conditions. No *Lingulæ* are known in the Lower Llandovery rocks; although 6 species occur in the Caradoc and 5 in the Upper Llandovery. The fauna generally may be regarded as one accumulating under decreasing depth or slow elevation over given areas. 8 of the 20 Lower Llandovery species pass to the Upper Llandovery or May-Hill beds. To show still further the decline in specific as well as individual members of the genus *Orthis*, I may mention that in the Upper Llandovery there are 10 species, but not a single form belongs truly to that horizon; *Orthis rustica*, the only true Upper Llandovery species, passes to the Wenlock rocks, so that no form of *Orthis* is special to the Upper Llandovery. The species of *Orthis* in the Wenlock rocks number 16, of which 8 come from the Llandovery and Caradoc and 4 pass to the Lower Ludlow (*Orthis biloba*, *O. crassa*, *O. elegantula*, and *O. hybrida*), so that *Orthis Edgeliana*, Salt., *O. Lewisii*, Dav., *O. Hughesii*, Dav., and *O. mullochensis*, var., or variety of *O. reversa*, are new and restricted forms. None pass to the Devonian. I have selected this genus in the Caradoc for comparison with the other Silurian groups on account of its magnitude and stratigraphical value. Two other genera, *Leptæna* and *Strophomena*, which first appear in the Llandeilo, also characterize the Caradoc by greatly increased specific development. These are *Leptæna* with 4 species and *Strophomena* with 2, both individually numerous in North and South Wales. In the Caradoc *Leptæna* yields 8 species and *Strophomena* 19, and for the first time we meet with *Rhynchonella* with 8 species; but no form is known to occur in South Wales, and only 3 have been found in North Wales. Ireland and Scotland yield 7 of the 8. The following Table shows the specific and stratigraphical value of these four important genera from the Cambrian to the Upper Silurian:—

	Longmynd.	Menevian.	Lingula-flags.	Tremadoc.	Arenig.	Llandeilo.	Caradoc.	L. Llandovery.	U. Llandovery.	Wenlock.	Ludlow.
Orthis	...	1	1	3	7	14	41	20	10	16	7
Leptæna...............	...	...	...	...	...	4	8	4	4	4	1
Strophomena.........	...	...	...	...	...	2	19	11	11	16	7
Rhynchonella	...	...	...	...	...	1	8	7	9	10	5
	0	1	1	3	7	21	76	42	34	46	20

Those genera having only one or two species are doubtless of equally high stratigraphic significance. Such are *Orthisina*, *Siphonotreta*, *Porambonites*, *Triplesia*, *Merista*, and *Meristella*.

Lamellibranchiata.—The known species of Bivalvia in the Caradoc and Bala rocks are more numerous than in any other Lower Palæozoic group. Thus the Tremadoc rocks of St. David's yield to us the earliest Bivalve fauna, consisting of 5 species; the Arenig has 6, the Llandeilo 6, the Caradoc 76, the Lower Llandovery only 3, the Upper Llandovery 29, the Wenlock 45, and the Ludlow 71. These numbers help us to see, by comparison, the zoological value of the class Conchifera in the several strata.

Ctenodonta, *Orthonota*, *Modiolopsis*, *Pterinœa*, *Ambonychia*, and *Palœarca* are the largest genera, or those having the most species, by comparison with the older and younger formations. The Caradoc Conchifera excel in number all beneath the Carboniferous. The following Table shows this, through the 6 Caradoc genera above named:—

	Longmynd.	Menevian.	Lingula-flags.	Tremadoc.	Arenig.	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock.	Ludlow.
Ctenodonta	...	...	...	2	...	1	17	...	6	3	4
Orthonota	...	...	...	...	...	...	5	1	6	3	16
Modiolopsis	...	...	...	4	1	2	16	...	3	6	5
Pterinæa	...	...	...	...	...	...	6	1	6	11	12
Ambonychia	...	...	...	...	...	...	8	...	...	2	1
Palæarca	...	...	...	...	2	1	5	...	...	...	...
	...	...	...	6	3	4	57	2	21	25	38

Cardiola with 3 species, *Mytilus* with 4, *Pleurorhynchus*, *Anodontopsis*, *Cucullella*, *Megalomus*, *Clidophorus*, *Arca*, and *Lyroderma* having each 1 species, complete the Conchifera of the Caradoc. Their geographical distribution is significant, but clearly shows the imperfection in collecting, and how much has yet to be done to demonstrate their relation to the extensive areas over which they ara distributed:—

Caernarvonshire	has yielded	6	genera and	16	species.
Denbighshire	,,	4	,,	7	,,
Montgomeryshire	,,	8	,,	14	,,
Merionethshire	,,	6	,,	19	,,
Pembrokeshire	,,	none		none	
Caermarthenshire	,,	2	,,	2	,,
Shropshire	,,	5	,,	10	,,
Westmoreland	,,	3	,,	3	,,
Scotland	,,	1	,,	1	,,
Ireland	,,	10	,,	37	,,

Nothing short of strict analysis could impress upon us the fact of such unequal distribution as the above examination shows. No species of bivalve is known in Pembrokeshire, a district rich in other groups. Only 1 genus and species in Scotland (*Pleurorhynchus dipterus*, Salt.), 2 only in Caermarthenshire (*Ambonychia triton* and *Ctenodonta varicosa*, Salt.), and 3 in Westmoreland (*Ctenodonta anglica*, D'Orb., *Pterinæa tenuistriata*, M'Coy, and *Cardiola interrupta*, Sow.). The physical geography of the area, either through barren or interrupted coast-line, rather than movements of land or depth of sea, would most probably account for this unequal distribution and poverty of species in one area, and their comparative abundance or fair representation in another. Looking at the horizons which the above 6 genera illustrate, and through which they pass, it seems hardly explicable that there should be only 3 species of Lamellibranchiata known in the Lower Llandovery, viz. *Pterinæa retroflexa*, *Mytilus mytilimeris*, and *Orthonota sulcata*; and these are Caradoc and Upper Llandovery also, showing us that not a single species belongs or is confined to the Lower Llandovery. This result, compared with the large bivalve fauna in the Caradoc or Lower Bala beds (57 species), and under conformable stratification, is scarcely to be accounted for, except through elevation of the sea-bed and change in bathymetrical conditions sufficient, with all other conditions, to cause the extinction or removal to another area of the Caradoc Lamellibranchs. Similar results are obtained with the Gasteropoda; the 53 Caradoc and Bala forms dwindle down to 16 in the Lower Llandovery. The Llandovery species will be noticed in their place or order subsequently. As before, Ireland yields the largest number of species (37).

Gasteropoda.—Like the three preceding classes, the group Gasteropoda is largely represented in the Caradoc strata; 14 genera and 53 species have been determined. No species has yet occurred in Pembrokeshire, and only 3 in Caermarthenshire (*Holopella cancellata*, Sow., *Patella saturni*, Goldf., and *Cyclonema crebristria*, M'Coy). Neither have we evidence of any species from Westmoreland, although, considering the somewhat abundant forms in Shropshire (9) and Scotland (11), and that the Westmoreland area intervenes, we might expect some to occur. The genus *Euomphalus* in Ireland (with 7 species), *Holopæa* in Merioneth (7), *Murchisonia* and *Rhaphistoma* in North Wales generally (12), constitute nearly one half the univalve fauna—*Trochonema, Turbo* ?, *Trochus* ?, and *Pleurotomaria* having but few species in each. 8 genera and 19 species actually pass up to the succeeding Llandovery, Wenlock, and Ludlow rocks above. The Lower Llandovery receives 10 species, and the Upper 16 ; the Woolhope 1 (*Turbo tritorquatus*, M'Coy), the Wenlock 2 (*Euomphalus alatus*, His., and *E. sculptus*, Sow.). 3 species range into the Ludlow—*Euomphalus alatus*, *Holopella cancellata*, and *H. conica*. Three species of Gasteropoda are common to the Llandeilo below—*Cyclonema crebristria*, *Murchisonia simplex*, and *Turbo tritorquatus*. The relationship of the two Llandoveries is marked ; the Lower has 103 species of all classes in common and the Upper 107, Ireland and Scotland possessing the highest numbers, being respectively 304 and 206.

Pteropoda.—Ten species of this class occur, the largest pelagic Pteropod fauna known in the Palæozoic rocks ; they occur in nearly equal numbers through the 10 areas, Ireland still yielding the highest number, nearly three times as many as Shropshire and Merioneth. No species is known in Pembrokeshire.

Heteropoda.—This order is represented in the Caradoc and Bala rocks by 11 species of *Bellerophon*, 2 of *Ecculiomphalus*, and 3 species of *Maclurea*. In the British area the two last-named genera are restricted in their geographical range to Ireland and Scotland, and stratigraphically to the Arenig or Llandeilo and Caradoc. *Maclurea* is known only in Scotland; *M. Logani*, Salt., *M. Peachii*, Salt., *M. macromphala*, M'Coy, and *M. magna* are said to be (in Scotland) of Llandeilo age. The Durness species, *M. Logani* and *M. Peachii*, with their associated forms, I believe to be Arenig. *Piloceras invaginatum* and *Orthoceras mendax* occur in the same beds. *Maclurea* abounds in the Chazy Limestone of the United States and Canada —beds probably to be correlated with our Lowest Llandeilo, the Upper Cambrian or Lower Bala group of Sedgwick. *M. M'Coyi*, *M. macromphala*, and *M. magna* are admitted to be with us of Caradoc age, and certainly occur low down in the series. Clonmel, Stinchar river and Bugon &c. in Ayrshire, and the Durness Limestones yield *M. Peachii* and *M. Logani* abundantly.

I have preferred to place *Ecculiomphalus* with the Heteropoda rather than the Pteropoda, although Portlock's genus may be one of the latter group.

Cephalopoda.—No less than 47 species have been determined from the Caradoc series; their maximum development is in Ireland, where 6 genera and 24 species occur; no species is known in Shropshire. Westmoreland and Scotland register 12 each. The Irish genera are *Cyrtoceras*, *Koleoceras*, *Lituites*, *Poterioceras*, *Trocholites*, and *Orthoceras*. As a generic fauna this is by far the largest in the Palæozoic rocks. Only one species (*Orthoceras arcuoliratum*, Hall) is common to the Caradoc and Llandeilo; but 15 species range upwards—7 to the Lower Llandovery, 9 to the Upper Llandovery, 4 to the Woolhope, 9 to the Wenlock, and 3 to the Ludlow; or the 15 make their appearance or occur 32 times in their range through the higher divisions of the Silurian rocks; 32 species are therefore essentially Caradoc or Bala forms. The numerical distribution of the Caradoc species through North and South Wales is remarkably uniform. 12 species occur in the four North-Welsh counties, and 8 in the two South-Wales counties. Shropshire possesses no Cephalopod, yet 57 genera and 123 species range through 13 zoological classes occurring in that county; but even this number represents numerically only a little over 2 species for each genus.

Table X. is prepared on geographical data, the universality or extension of the Caradoc rocks and species not admitting of any other mode of expressing their distribution; and to analyze the group under subdivisions of the Caradoc or Bala, as given by various authors, would end in confusion, owing to the application of the terms Lower, Middle, and Upper Caradoc, or Bala, not being the same in all. Text-books have not yet defined the limits of these divisions, either zoologically or geographically; in the former sense the greatest difficulty would be felt over extended areas, through want of true succession and continuity in strike. A careful study of the Woodwardian Catalogue demonstrates the difficulty of treating the Caradoc or Bala group as a whole in any other way. The column headed "Localities and Numbers" in that Catalogue at once shows that it is only through space distribution that we can realize the value of the subdivision. In the Lower Bala group of the Upper Cambrian, as established by Sedgwick, Mr. Salter has placed 45 genera and 82 species; in the Middle Bala 82 genera and 212 species; and in the Upper Bala group 43 genera and 100 species. That the fossils of the "Lower Bala" of the Woodwardian Catalogue represent the Llandeilo proper of the Geological Survey there can be no doubt; and out of the 82 species catalogued, only 17 pass to the Middle Bala group, and 8 to the Upper Bala. The Middle Bala of the Cambridge Catalogue receives the fine assemblage of fossils collected from the Bala limestone, sandstones, and slates of North Wales, the Caradoc sandstones and the Horderly limestones of Shropshire, or the true Caradoc. It includes also the fossils of the Coniston Limestone, the Kildare, Craig-Head, and Peebles Limestones. The Hirnant Limestone is not included in Sedgwick's Middle Bala, but constitutes the base of his Upper Bala group. The 212 species largely illustrate the characteristic fauna of the Caradoc, and the group clearly shows the value of the division (especially with the elimination of the Llandeilo forms) and its separation from the Lower Llandovery (the Upper Bala of Sedgwick), into which only 33 of the 212 species passed. These proportions in the Cambridge collection (as catalogued), showing the community of forms between the 3 divisions, show how well the collection was made, and also the care bestowed upon the stratigraphical grouping of the fossils. The Upper Bala group of Sedgwick includes the Aber-Hirnant Limestone, which occurs above the Bala Limestone, also the lower part of the Coniston Flags, the beds above the Bala Limestone, and below the May-Hill Sandstone; it therefore includes the Lower Llandovery or Mathyraful Limestone near Meifod, and also the rich fossiliferous series at Haverfordwest, the Dalquorhan and Mulloch beds of Scotland, and the Maume and Cong beds of Galway *. The Woodwardian Catalogue enumerates 43 genera and 100 species from this group (the Lower Llandovery of the Geological Survey), 18 genera and 36 species of which also occur in the Middle Bala below.

Lower Llandovery.

In my analysis of the Lower Llandovery species from the rocks of that age in North and South Wales, Scotland, and Ireland, I have brought together and tabulated all that is known relative to the range and distribution of life through this Middle Silurian or Upper Bala group of Sedgwick. The table shows the value of this upper member of the Caradoc or Bala beds, and its relation to the transitional Upper Llandovery, or the group so called, which stands between and connects the Lower Silurian of the Survey with the well-defined succeeding Wenlock and Ludlow series. Careful analysis of the species in both their stratigraphical and geographical distribution shows how small a specifically characterized group the Lower Llandovery appears to be, for only 115 species out of 204 are really Lower Llandovery. The total number of genera and species known for all Britain is 68 genera and 204 species; but 50 *genera and* 104 *of these species transgressed* or came from the Caradoc and Bala beds below, thus reducing the actual Llandovery fauna to 18 genera and 100 species. The intimate connexion with the Upper Llandovery is chiefly through the Actinozoa (20 species), Brachiopoda (38), Crustacea (10), and Gasteropoda (8). No form of Protozoa, Echinodermata, or Pteropoda is common to the two Llandoveries in any area in Britain.

No species of Echinodermata occurs in North Wales, Ireland, or Westmoreland. No Lower Llandovery Annelid is known in North Wales. Neither do we know of any Lamellibranch, Pteropod, Heteropod, or Cephalopod in the same area. I will now discuss through tabular analysis the distribution of the chief zoological groups in the Lower Llandovery, viz. the Echinodermata, the Crustacea, Brachiopoda, and Gasteropoda. The remaining 7 of the 13 groups (there being no plants) are conspicuous through feeble representation, due doubtless to geographical changes towards the close of the Caradoc and Bala period.

Hydrozoa.—The careful researches and generalizations of Linnarsson in Sweden, Lapworth, Nicholson, Carruthers, and Hopkin-

* *Vide* Cat. Coll. Cambrian and Silurian Fossils in Mus. Univ. of Cambridge, pp. 25, 26, 39, & 72, for greater details.

TABLE X.—*Caradoc.*

From Llandeilo.	Classes.	Genera.	Species.	Geographical Distribution. North Wales. Caernarvonshire.	Denbighshire.	Montgomeryshire.	Merionethshire.	South Wales. Pembrokeshire.	Caermarthenshire.	England. Shropshire.	Westmoreland.	Scotland.	Ireland.	Pass to Lower Llandovery.	Upper Llandovery.	Woolhope.	Wenlock.	Ludlow.
	Protozoa	9	10	1/1	2/1	2/2	...	2/2	2/2	4/4	2/2	4/4	4/4	3/3	...	1/1	1/1	1/1
9/16	Hydrozoa	21	38	4/4	...	...	...	...	...	4/4	...	20/38	13/20	1/1				
3/3	Actinozoa	20	40	4/4	8/16	5/12	4/8	7/12	4/6	4/7	10/20	16/26	7/9	9/20	6/17	4/7	9/17	4/7
2/2	Echinodermata	15	32	4/4	4/5	5/7	7/16	5/13	3/3	3/4	1/3	...	4/7	2/2				
	Annelida	11	16	1/4	3/3	2/2	4/4	4/4	4/4	4/4	2/2	5/6	4/5	2/2	2/2	1/1	3/4	3/4
9/16	Crustacea	37	146	13/20	17/33	15/29	16/36	16/24	11/16	15/31	18/35	31/78	31/90	10/16	11/17	6/8	8/9	5/8
	Bryozoa	7	21	2/2	3/8	4/11	5/8	2/6	1/2	2/3	3/5	1/3	3/6	2/4	2/6	2/2	2/2	1/1
7/14	Brachiopoda	15	109	6/29	9/39	8/45	10/41	4/26	6/25	7/39	7/36	11/49	13/61	8/33	9/27	5/12	6/14	3/5
2/3	Lamellibranchiata	16	76	6/16	4/7	8/14	6/19	...	2/2	5/10	4/4	7/7	10/37	3/3	5/7	3/3	8/11	9/12
2/3	Gasteropoda	14	53	6/12	6/9	3/9	6/17	...	3/3	6/9	1/1	6/20	12/27	6/10	8/16	1/1	1/2	2/3
1/1	Pteropoda	3	10	1/1	1/1	1/1	2/3	...	1/2	2/3	2/2	4/6	4/8	1/1	2/2	...	2/2	1/1
2/4	Heteropoda	3	16	1/5	1/4	1/4	1/3	1/1	1/3	1/5	1/1	2/10	1/8	1/1	1/4	1/4	1/2	1/2
1/1	Cephalopoda	8	47	2/3	3/5	2/2	3/7	3/5	3/4	...	3/12	2/15	6/24	2/7	2/9	2/4	3/9	2/3
38/73	....	179	614	51/105	61/131	56/138	64/162	44/93	41/72	57/123	54/123	109/262	111/306	50/103	49/107	26/43	44/73	32/47

son in Britain, Hall in America, and Barrande in Bohemia, upon the history, morphology, and distribution of the Rhabdophora through the Lower Palæozoic rocks of Britain, Europe, and North America, have greatly added to our knowledge of their stratigraphical value and distribution both in time and space. To no author, however, are we so much indebted as to Mr. Lapworth for his exhaustive researches in this department of Palæontology. Until his careful analysis and descriptions of the Rhabdophora, as well as the physical relations, of the Moffat series in Scotland, and his able papers in the Ann. & Mag. Nat. Hist. ser. 5, vols. iii.–vi., we had little clear knowledge either of their zoological grouping or stratigraphical distribution and relations to other geographical areas, either in Britain, Europe, or America. That the southern Highlands or uplands of South Scotland yield rocks of a peculiar character is well known. They consist of two types—coarse greywacke, grey, green, or purple in colour, associated with fissile flagstones, which either alternate with the greywacke, or are arranged separately in zones of considerable thickness. These two types preponderate. "On the west coast, near Girvan, limestones, shelly sandstones, and mudstones yield fossils in great profusion, and both mineralogically and palæontologically remind us of the most prolific areas of Wales and Shropshire."

Certain beds of black carbonaceous shales and mudstones occupying "long lenticular areas occur in the great mass of barren greywacke; they form extended moniliform lines of great extent, and range at intervals throughout the northern half of the Southern Uplands, from the Irish Channel to the North Sea; these black shales everywhere swarm with Rhabdophora." It is this group of Graptolitiferous strata of the south of Scotland (the Moffat series), and their physical and zoological relations to deposits in other areas, that Mr. Lapworth has made classical. We know of few or no Lower or Upper Llandovery Hydrozoa in Wales. The Coniston Mudstones (Westmoreland) yield 6 genera and 25 species; and these probably belong to the Lower Llandovery series. The value, however, of the Scotch deposits, and their Graptolitic fauna of 50 or more species, is very great; they clearly show us that the paucity of species in the Welsh rocks is probably due to geographical and other physical changes.

South of Westmoreland this group had scarcely a representative after the deposition of the Caradoc, none having survived the close of the Upper Bala period; for the Lower Llandovery in North Wales has yielded few or no species; the Upper Llandovery and the succeeding Wenlock group, through the Tarannon beds, 5 genera and 23 species; North Wales 4 genera and 8 species, and South Wales 8 genera and 11 species; Westmoreland 3 genera and 12 species; Ireland none. These several numbers are as near as I can bring them, knowing the difficulty of understanding the Llandovery question, and omitting in North Wales the sandy or arenaceous Llandovery, which (in that area) does not appear to have furnished a congenial habitat for the growth and development of the Rhabdophora. Highly favourable, however, the conditions seem to have been during the formation of the Arenig, Llandeilo, Caradoc, and Lower Llandovery deposits, as shown in the following table :—

Arenig	17	genera and	24	species.
Llandeilo	18	„	44	„
Caradoc	21	„	38	„
Lower Llandovery of South Wales	5	„	17	„
Lower Llandovery of Westmoreland	6	„	25	„
Lower Llandovery of Scotland	7	„	52	„
Upper Llandovery	4	„	12	„
Wenlock	9	„	23	„
Ludlow	3	„	8	„

I mention these facts and results here rather than under the Ludlow section, as the group of the Graptolitidæ are conspicuous here, and they are of little value in classification above the Llandovery rocks. It may be remembered that in 1872* Prof. H. A. Nicholson published, in the Journal of the Geological Society, a paper of great originality and highly suggestive of the mode of migration and distribution of the Graptolites in time and space, or the vertical and lateral range of this group of fossils. In this paper Prof. Nicholson endeavours to show the peopling of one area as derived from another and from points widely separated, showing that under such circumstances they can never be truly contemporaneous. "In the present state of our knowledge, however, it must be more or less provisional and tentative" to attempt to trace the migrations of any given set of species or groups of fossils; but probably the time will arrive when definite groups under given conditions may receive elucidation for lateral range, especially when the original area of occurrence and dispersion is known. Dr. Nicholson argues, and justly, that "if we were thoroughly acquainted with the range of any given fossil or species vertically, and were conversant with all the details of its geographical distribution, we should then be able to lay down with some degree of accuracy the lines along which it must have migrated when the condition of its original area became unsuitable for its further existence therein." Prof. Nicholson endeavours to show in his paper certain facts relating to the distribution of the Graptolites, so as to enable us to sketch out the migrations of these and other organisms from their first appearance in time; in the case of the Rhabdophora from the Arenig to their final disappearance at the close of the Ludlow deposits. Five areas are selected to illustrate the distribution of the Graptolites:—1st. The Skiddaw group and its Arenig fauna, as being the earliest in which the Graptolites appeared, and probably the first area, for we have no reason to believe that the Canadian or Quebec deposits much preceded in time our own Cumberland series; the large number of genera and species not only common to the Skiddaw Slates of the north of England and the Quebec group, but exclusively confined to them, conclusively and distinctly prove that the area was no small one.

* Quart. Journ. Geol. Soc. vol. xxviii. pp. 217–232 (1872). "Migrations of Graptolites," by H. A. Nicholson, M.D., D.Sc., &c.

The differences, indeed, between the Graptolitic faunas of the Skiddaw and Quebec regions are not greater than what may be due to imperfect observation, or the effect of difference of station, without either supposing that one region was peopled by migration from the other*.

The second area discussed by Dr. Nicholson is that of Wales and Scotland, containing the Llandeilo Graptolites. The auther believes that the north of England was dry land during the early portion of the Llandeilo period, and also that the close of the Skiddaw (Arenig) period was signalized by the upheaval of the Lake district; this, or the unfitness for life of the succeeding seas, in consequence of igneous activity, may have been the cause of no deposits containing Graptolites being superimposed upon the Skiddaw Slates, until we reach the higher or later portion of the Caradoc or Bala period (the Lower Llandovery), at which time an immigration of Graptolites must have taken place from neighbouring seas. On such hypotheses, supported by details too minute to discuss here, we may realize the absence in certain areas of zoological groups whose existence necessitates the deposition of sedimentary matter congenial to their growth and development. Why the Lower and Upper Llandovery rocks of North and South Wales do not possess a larger Graptolitic fauna, when in the north of England and Scotland such a fauna is well developed, can only be explained through physical changes, either movements of land and sea, or interference through sedimentary agency, of which there may be many kinds.

Dr. Nicholson further enters into the consideration of the second great Graptolitic period of the north of England, during which the mudstones of the Coniston series were deposited. In the Coniston Limestone proper, which corresponds to the Bala Limestone, no species have occurred, it being wholly barren of Hydrozoa; but the so-called Graptolitic mudstones succeeding it abound in species, 6 genera and 25 species having been recorded from them. Many of these (16) Nicholson believes have been derived from the Upper Llandeilo of the south of Scotland, the remaining 9 being peculiar to the Coniston Mudstones. The fourth area Dr. Nicholson calls the Gala area of the south of Scotland, in Dumfriesshire; Mr. Lapworth applied to these deposits the name "Gala Group." Eight species in this Gala series are derived from the Upper Llandeilo of the Scotch area, and the remaining 5 (of the 13) are importations from the Coniston Mudstones and Coniston area of the Lake district.

The Hudson-River shales and Utica Slates Nicholson believes to have been peopled by a great migration of the Upper Llandeilo Graptolites of the south of Scotland, which appear to have taken a westerly course, and ultimately to have reached the United States, there forming the Graptolitic fauna occurring in the Caradoc or Hudson-River shales and Utica Slates described by James Hall. This view of Nicholson's, that the Graptolites of the Hudson-River group are derived through migration from the Upper Llandeilo of the south of Scotland, he supports or illustrates by means of a table of

* Nicholson, Quart. Journ. Geol. Soc. vol. xxviii. pp. 218, 219.

24 species of Graptolites, 13 of which are so derived. These are associated with 1 from the Skiddaw and 8 peculiar to the Hudson-River deposits. Nicholson, in his fifth, or Saxon and Bohemian area, endeavours to show that two great migrations of Graptolites took place from the area of the south of Scotland at the close of the Upper Llandeilo period, one westward through Ireland to America, the other southward into the north of England; and he suggests a third migration from the same area in a south-easterly direction, or into the Silurian seas of Saxony and Bohemia. Geinitz, in his "Grauwackenformation" of Saxony, believed the Graptolitiferous rocks to be the summit of the Lower Silurian series (Llandovery). Of 5 genera and 12 species given, 4 genera and 10 species are derived from the Upper Llandeilo of the south of Scotland, and 2 from the Coniston Mudstones. Barrande has recognized the British derivation of the Bohemian Graptolites ('Défense des Colonies,' 1870); he recognizes two chief Graptolitic zones in Bohemia, viz. Etage D at the summit of the Lower Silurian series, and Etage E at the base of the Upper. The Bohemian Graptolites derived from Britain number 5 genera and 14 species, and are believed to be derived through migration from the Coniston Mudstones or Upper Llandovery beds of the north of England. These are identical species with those which lived in the mudstones named*. I have thus shown that it is only in Scotland and Cumberland that we obtain a Graptolitic fauna in the Llandovery rocks (probably Lower), and that none occur in either of the two Welsh areas†.

Actinozoa.—The species of this class in the Lower Llandovery number a fraction more than 2 to each genus, of which there are 12 (and 26 species). The genera *Favosites*, *Heliolites*, and *Petraia* abound most in species—*Favosites* 5, *Heliolites* 4, *Petraia* 6. The distribution for North Wales is 5 genera and 8 species; for South Wales 8 genera and 16 species; and for Ireland the same number. Singularly just as many species pass to the Upper Llandovery (20) as came up from the Caradoc and Bala beds (20), and in each case 9 of the same genera; so that in reality the Lower Llandovery rocks possess only 6 species of Actinozoa peculiar to them, so closely allied are the two formations through this, as through other groups of fossils. 7 of the 9 genera have as yet only yielded 1 species each. Nothing can be more unsatisfactory than the evidence afforded by such scanty materials; close research would result in yielding numerous and more definite species.

Echinodermata.—No species is known either in North Wales or Ireland, and two species only in South Wales—*Echinosphærites arachnoidea* and *Glyptocrinus*, sp. (stem-ossicles). This last genus occurs in Scotland also; neither pass to higher formations, but the same two species occur in the Caradoc.

* Nicholson, *loc. cit.* pp. 228–230.

† Recent researches by Lapworth into the specific value and history of the Rhabdophora have tended to reduce the number of species, great numbers of so-called species being established on mere fragments of other species. Their elimination will be of great value to the student of this difficult class of the animal kingdom.

Crustacea.—The Crustacea of the Lower Llandovery reveal to us numerically only 2 species in each genus. We have much yet to learn of the history and zoological relations of the Trilobita of the Llandovery rocks. The 13 genera and 25 species of this order mostly characterize the rocks of South Wales and Scotland; 2 genera and 4 species only are known in North Wales, *Calymene* (3) and *Trinucleus* (1); and 7 genera and 8 species in South Wales; Scotland has 9 genera and 16 species. Eighteen of the Trilobita are also Caradoc; and 8 genera and 10 species pass to the Upper Llandovery; so that in the Lower Llandovery one of its largest groups has little or no stratigraphical value in classification.

Brachiopoda.—This class, like the Crustacea, has little or no classificatory value; for of the known 10 genera and 59 species in the Lower Llandovery, 8 genera and 35 species are also Caradoc and Bala, and 10 genera and 38 species pass to the Upper Llandovery. The characteristic species are *Meristella subundata*, *Orthis Bouchardi*, *Rhynchonella tripartita*, *Spirifera exporrecta*, *Strophomena arenacea*, *Stricklandinia lens*, *Pentamerus oblongus*, and *P. undatus*. The first appearance of *Pentamerus* and *Stricklandinia* is a marked and important feature in the Lower Llandovery beds. Three species of *Pentamerus* (*P. oblongus*, *P. globosus*, and *P. undatus*) are Lower and Upper Llandovery forms; the 2 species of *Stricklandinia*, *S. lens* and *S. lirata*, are common to both horizons. In North Wales, 8 genera and 22 species occur; and in South Wales 10 genera and 48 species; Scotland has yielded 8 genera and 29 species, and Ireland 9 genera and 27 species. The South-Wales beds are enriched chiefly through the genus *Orthis* with 20 species, *Strophomena* with 11, and *Rhynchonella* with 7.

Lamellibranchiata.—No species of this extensive group of Mollusca occurs either in North Wales or in Scotland; and we are only acquainted with 3 genera and 3 species in the Lower Llandovery, viz. *Pterinæa retroflexa*, *Mytilus mytilimeris*, and *Orthonota sulcata*; these 3 are South-Wales forms, and the *Pterinæa* occurs in the Irish Llandovery. This meagre representation of so large a class in these beds, as compared with the Caradoc with 16 genera and 76 species, clearly shows that at the close of the Caradoc and Bala period great changes took place with regard to the relations of land and sea. The Caradoc sea evidently shallowed and reduced its area, and this was accompanied by corresponding sedimentary changes which governed the life, habits, and distribution of the succeeding Llandovery fauna. This is borne out by the Brachiopoda and other groups which reached such perfection in the Caradoc seas (109 species), Crustacea (146 species), the Lamellibranchs (76 species), Gasteropoda (53 species), and Cephalopoda (47 species); whereas in the Lower Llandovery many of these groups are scarcely represented; for example, the group we are now treating of has only 3 species, the Echinodermata 2, theGasteropoda 16, and the Cephalopoda only 3, with only 1 species of Pteropod and 1 Heteropod.

Doubtless the strictly arenaceous nature of the deposits and the somewhat shallow sea constituted the main cause of this extremely small bivalve fauna. Two of the three species of Conchifera are Caradoc, and the same two passed to the Upper Llandovery, so that in reality only 1 species is to be regarded as Lower Llandovery.

Gasteropoda.—Although this class includes a much greater number of species than the Lamellibranchiata, yet the value of the fauna for classificatory purposes is equally unsatisfactory. 9 genera and 13 species are known; but of these 6 genera and 10 species are Caradoc and Bala forms, and 6 genera and 8 species are common to the two Llandovery series. Only 1 species is known in North Wales (*Murchisonia pulchra*, M'Coy), 5 genera and 9 species in South Wales, and 6 genera with 6 species in Scotland and with 7 in Ireland. Thus only 6 species of Gasteropoda are truly of Lower Llandovery age—*Murchisonia Pryceæ*, *M. sulcata*, *Platyschisma Williamsoni*, *Acroculia haliotis*, *Trochus Moorei*, and *T. multitorquatus*.

Pteropoda.—The only Pteropod occurring in the Lower Llandovery is *Conularia Sowerbyi*, Def., and this has only appeared in South Wales and Scotland; none are known in North Wales or Ireland. This species bridges over the Upper Llandovery, Denbighshire Grits, and Woolhope series, and reappears in the Wenlock Shales and Limestones in South Wales and Scotland.

Heteropoda.—*Bellerophon carinatus*, *B. bilobatus*, and *B. dilatatus*? are the chief Lower Llandovery species. The same 3 are Caradoc, and *B. carinatus* and *B. bilobatus* also occur in the Upper Llandovery of South Wales and Scotland, *B. dilatatus* being Irish also.

The species of these two nocturnal and pelagic groups, the Heteropoda and Pteropoda, from their habit, had a wide geographical distribution, and consequently a long range in time also.

Cephalopoda.—We have seen that the Lower Caradoc and Bala rocks have yielded no less than 8 genera and 47 species; the Lower Llandovery, the highest member of the Bala formation, has, on the contrary, only 3 genera and 8 species distributed through the 6 areas in which this formation is represented. The genera are *Lituites*, *Tretoceras*, and *Orthoceras*. The first-named genus has 2 species, *L. cornu-arietis* and *L. undosus*; the second (*Tretoceras*) 1 species, *T. bisiphonatum*; and *Orthoceras* contains 5 species, *O. annulatum*, *O. ibex*, *O. politum*, *O. tenuistriatum*, and *O. vagans* (?). Of these no species occurs in North Wales. South Wales, however, in the Llandovery area, has yielded 5 species, Scotland 2 (*Orthoceras politum* and *O. tenuistriatum*), and Ireland 1 species (*Orthoceras ibex*). Four of the 8 pass to the Upper Llandovery, and 7 came from the Caradoc. *Tretoceras bisiphonatum* and *Lituites undosus* are the only restricted Lower Llandovery species out of the 8 known.

The accompanying table shows the complete census of the Lower Llandovery rocks, and their relationship to the Caradoc below and the Upper Llandovery above, and at once reveals the fact that this upper member of the Bala group has no claim to separation from it; for 50 genera and 105 species unite it with the Caradoc and Bala proper, and 45 genera and 104 species pass to the Upper Llandovery; and we shall find, on casting the life-history of the Upper Llandovery also, that nearly one half of both genera and species are also so-called Llandovery; or out of 91 genera and 240 species known in the Upper Llandovery, the above 45 genera and 104 species occur in the lower group also. Only 16 genera and 101 species are therefore really Lower Llandovery.

Table XI.—*Lower Llandovery.*

From Caradoc.	Classes.	Genera.	Species.	Geographical Distribution.					Pass to Upper Llandovery.
				North Wales.	South Wales.	Scotland.	Ireland.	Westmoreland.	
	Plantæ								
3/3	Protozoa	3	3	2/2	3/3	1/1			
1/1	Hydrozoa	7	50	...	5/17	7/45	7/32	6/25	3/15
9/20	Actinozoa	12	26	5/8	8/16	7/11	8/15	...	9/20
2/2	Echinodermata	2	2	...	2/2	1/1			
2/2	Annelida	2	3	...	2/2	1/1	1/1	...	2/2
10/16	Crustacea	13	25	4/6	8/10	10/19	7/8	...	8/10
2/4	Bryozoa	2	5	2/4	2/3	1/2	1/2	...	2/3
8/35	Brachiopoda	10	59	8/22	10/48	8/29	9/27	...	10/38
3/3	Lamellibranchiata ..	3	3	...	2/2	...	1/1	...	2/2
6/10	Gasteropoda	9	13	1/1	5/9	6/6	6/7	...	6/8
1/1	Pteropoda	1	1	...	1/1	1/1			
1/1	Heteropoda	1	6	...	1/2	1/2	1/1	...	2/2
2/7	Cephalopoda	3	8	...	3/5	1/2	1/1	...	1/4
50/105	....	68	204	22/43	52/120	45/130	42/95	6/25	45/104

Upper Llandovery, or May-Hill Group.

Perhaps no formation in the Lower Palæozoic series is more difficult to understand, either physically or zoologically, than the "Upper Llandovery," or May-Hill group. Its place, stratigraphically, was long ago settled by Sedgwick, who was the first to point out the necessity for separating these beds from the Lower Silurian (his Cambrian), and removed them from the Caradoc in 1853, proposing the name of the "May-Hill Sandstone" for these beds, being above all his Cambrian Rocks; and this is so throughout the northern hemisphere.

On the west flank of the Malverns, at Woolhope, May Hill, and

Tortworth, in many localities in Shropshire (Norbury, Cherbury, Church Stretton, &c.), and at Llandovery, Presteign, &c. in South Wales, the Upper Llandovery or May-Hill beds are typically exposed.

Many names have been proposed for these variable beds, such as Upper Caradoc, *Pentamerus*-beds, Wenlock Grit, &c.; but, through their chief development at Llandovery and May Hill, in Gloucestershire, the double name of the "Upper Llandovery," or "May-Hill Sandstone," has been given to them. In North Wales the Upper Llandovery rocks are absent; in South Wales they first appear in Marloes Bay, appearing here and there across Pembrokeshire. Near Llandeilo, in Caermarthenshire, they lie at the base of the Upper Silurian rocks, being most variable in thickness. They transgress or lie indifferently and unconformably on Lower Llandovery, Caradoc, or Llandeilo beds. In Shropshire they are markedly unconformable to the Caradoc. In the Longmynd area, under the condition of a calcareous conglomerate, they rest upon all the older rocks exposed. That a great physical break takes place between the two Llandoveries there can be no doubt. They rise from under the Wenlock Shale at Noeth Grug, strike to near Llandovery and Pen-y-lan; again they range uninterruptedly from Marloes Bay, in Pembrokeshire, where they are highly fossiliferous (28 species occurring there), through Caermarthenshire to Builth, and on to the Longmynd and typical Silurian country of Shropshire. They everywhere rest unconformably upon the older rocks, sometimes lying on the denuded edges of the Lower Llandovery or on the Caradoc Sandstone; at Builth and the Longmynd on the contorted and denuded Arenig, Llandeilo, and Cambrian strata.

The absolute unconformity of the Upper Llandovery beds to the strata below, coupled as it is with changes of species, is doubtless connected with a lapse of unrepresented time. Whether that time be of great duration or not we have no means of judging; but, looking at the intimate connexion between the fauna of the Lower Llandovery and that of the Upper, we are led to *suppose that it was not of sufficiently long duration to cause either the extinction or migration of the older fauna or the introduction of a new one* (only 4 genera seem to have appeared); for we have seen that the Lower Llandovery transmitted 45 genera and 104 species, out of its fauna of 68 genera and 204 species, to the Upper Llandovery. It is therefore evident that upheaval and denudation must have been of comparatively short duration, and little physical change could have taken place in the area occupied by the Lower Llandovery after upheaval; this the physical geography and palæontology of the two groups help to show.

The preponderance of individuals in species of the genera *Pentamerus* and *Stricklandinia*, especially *P. oblongus*, *S. lens*, and *S. lirata*, which are the best known and most widely spread, is a marked feature in the Upper Llandovery rocks, and imparts to them peculiar and distinct facies. These species occur, though not so plentifully, in the Lower Llandovery. The Malvern and May-Hill form is *S. lens*, and it occurs in profusion. Looking at the grouping of the

Upper Llandovery and the distribution of its fauna, we are surprised to find that, of the 261 species which occur in the formation, only 136 species really constitute the Upper-Llandovery fauna. The fact that 104 of the species are Lower Llandovery goes very far to unite the two so-called formations into one, or a Middle-Silurian group, abolishing the terms Lower and Upper. Granting the high value of the unconformity as of paramount stratigraphical importance, yet the community of fossils and general facies of both horizons lead us to regard the species as belonging to neither; for certainly the Lower Llandovery was an expiring close to the Caradoc and Bala, through elevation of the Caradoc sea-bed, and the Upper through continuity of certain species; and the introduction of new forms commenced at the base of the Upper Silurian of Sir R. Murchison and the Geological Survey, from which, in the Wenlock rocks, were derived 58 genera and 125 species; for out of the 523 Wenlock, 125 are Upper Llandovery, 136 species only being the true Upper Llandovery fauna proper.

Plantæ.—One species only, a fucoid (*Fucoides gracilis*), is known in this group of strata. This is probably only one of the many forms of Annelide or molluscan tracks or burrows, which simulate the habit of some of the marine algæ.

Protozoa.—*Clathrodictyon vesiculosum*, Nich., and *Cliona* (*Vioa*) *gracilis* constitute the only two Protozoa known. The former occurs in the Llandovery rocks of Scotland; the latter appears to be a dichotomizing, burrowing sponge, found in the shelly structure of a *Pterinæa* (*P. demissa*) from the Upper Llandovery of the Malvern Hills. This is probably the oldest known *burrowing* sponge; its habit is quite that of the modern genus *Cliona*.

The Welsh Llandovery rocks, although so carefully searched, have yielded no traces of Spongidæ. We should, however, quite expect to find the group Silicipongiæ, through the Hexactinellidæ, represented in these sediments or formations accumulated in moderately deep water, and associated with an extensive Cœlenterate and Brachiopodal fauna, such as we have in the Upper Llandovery. The Analytical Table (p. 159) shows that only in two of the ten (Worcestershire and Scotland) are the Protozoa known.

Hydrozoa.—The genera *Monograptus*, *Cyrtograptus*, *Diplograptus*, and *Retiolites* alone seem to represent the Rhabdophora in the Upper Llandovery rocks; but so many species appear to be common to the Lower and Upper Llandovery, that it is with difficulty I am enabled to realize the distinctness of the two faunas. The Irish, Scotch (Girvan, Gala, and Mulloch beds), and the Coniston flags and mudstones have so many species in common with the Lower Llandovery that only through intimate and practical acquaintance with the two groups of species can they be separated. In the Valentian or Llandovery-Tarannon series of Lapworth, including the Birkhill series and its several zones, so many species of *Monograptus*, *Diplograptus*, and *Cyrtograptus* appear to be common, that it is no easy task to determine numerically or statigraphically, especially when geographical distribution is also taken into consideration, their true history. Probably the Upper Llandovery rocks of Ireland yield 6 or 8 species, the Girvan beds about 30, the Gala group the same, the Mulloch beds 25 species, and the Coniston beds 25 species; but many also belong to the Lower Llandovery below and elsewhere. The species in two of the genera above named, *Monograptus* and *Cyrtograptus*, increase in the Wenlock; in which, if we include the species which occur in the Tarannon Shales lying at the base of the Upper Silurian (Lower Wenlock group), some 9 genera and 20 species may occur. As in the Caradoc, it is extremely difficult to arrive at the number of true species that range through the areas, owing to not having correct knowledge of the species.

Actinozoa.—This is, zoologically, an important group in the Upper Llandovery, from the number of genera occurring and the numerically few species, 11 of the 16 genera being represented only by 1 species each. These are *Alveolites*, *Cœnites* (probably one genus), *Halysites*, *Labechia*, *Omphyma*, *Plasmopora*, *Ptychophyllum*, *Lindströmia*, *Propora*, *Pinnacopora*, and *Streptelasma*. Thus only 5 genera constitute a specific fauna, viz. *Favosites* 4 species, *Heliolites* 5, *Palæocyclus* 2, *Petraia* 7, and *Syringopora* 3. Their dispersion or distribution is equally significant, showing that the two chief compound genera, *Favosites* and *Heliolites*, are, with one exception (*Petraia*), the most widely distributed geographically. *Petraia* occurs in all the 14 localities*; and perhaps no single genus has so wide a range or such persistent representative forms, commencing in the Caradoc with 6 species, having the same number in the Lower Llandovery, and 7 species in the Upper Llandovery. It is reduced to 3 in the Wenlock, and 1 (*P. bina*) in the Lower Ludlow. We know also of 3, if not 4, *Petraiæ* in Lower, Middle, and Upper Devonian; they are, however, distinct species, being *P. celtica*, Lonsd., *P. gigas*, M'Coy, and *P. pleuiradialis*, Phil. As regards the number of genera and species numerically of value, or important in certain areas, we find that in Pembrokeshire and Cardiganshire these are but feebly represented. The former county, at Marloes Bay, has given us 3 genera and 4 species, viz. *Favosites asper*, *Omphyma turbinata*, *Petraia bina*, and *Petraia subduplicata*; and Cardiganshire only 1, *Petraia elongata*. Radnorshire has yielded 2 genera and 3 species, *Heliolites interstinctus*, *Petraia elongata*, and *P. subduplicata*. These few and local species are significant and suggestive as to the cause of their restricted numbers. Worcestershire, through the Malvern area, is richest in species, its 7 genera and 18 species being the highest known in the nine areas—Caermarthenshire and Caernarvonshire having 12, Gloucestershire, Scotland, and Ireland each 10 species, and South Wales generally 14. Of the 16 genera and 32 species that range through the Upper Llandovery beds, 14 genera and 22 species pass up into the Wenlock. The 3 genera peculiar to this horizon are *Propora* (*P. Edwardsii*), *Pinacopora* (*P. Andersoni*), and *Lindströmia* (*L. lævis*). The remaining genera and species all pass to the Wenlock series, the Cœlenterate fauna of which numbers 76 species.

* *P. subduplicata* has recently been discovered in Scotland.

Echinodermata.—It is clearly shown that this group requires to be more carefully collected and studied. We have 5 genera and 5 species, or only 1 representative species to each genus. None occur in Shropshire or Scotland. Two species, representing 2 genera, have been met with in Pembrokeshire. The species are *Actinocrinus pulcher?*, *Cyclocystoides Davisii*, Salt., *Palæaster coronella*, *Periechocrinus moniliferus*, and *Palæechinus Phillipsiæ*, Forbes—the last being the first known representative of the Echinoidea in time. The Perischoechinidæ, to which family this genus belongs, attained its maximum development during the Carboniferous period, both in Britain and America. No fewer than 7 genera have been recognized in America and 4 in Britain. In the test of *Palæechinus* the interambulacral plates abut against each other, not being bevelled for overlapping articulation, as is the case with *Perischodomus*, *Oligophorus*, *Melonites*, and other genera. The family Archæocidaridæ, of which the Carboniferous genus *Archæocidaris* is the type, does not occur below the Carboniferous rocks in any known area. The modern representative, "*Calveria*" (*C. hystrix*) of Prof. W. Thomson, has been dredged in 445 fathoms water (2670 feet) in lat. 59° 38′ N., long. 7° 46′ W. *Calveria* differs from all known recent Echinoidea through the structure of the plates of the test, which overlap, instead of abutting against each other, as in all other genera. Again, the plates composing the interambulacral areas overlap from the apical disk towards the mouth, and those of the ambulacral area from the mouth towards the apical disk, or in the reverse direction. This ancient type appears in the Chalk as *Echinothuria* (*E. floriformis*); and now, through the dredgings of the 'Porcupine,' we have proof of its continuity from the Cretaceous epoch.

Annelida.—Three genera, with four species, two of which claim attention here, viz. *Tentaculites* (*ornatus*, Sow.), and *Cornulites* (*serpularia*, Schloth.). They have occurred in almost every locality since their first appearance in the Caradoc and Bala beds. *Tentaculites* ranges through the Caradoc everywhere except in Scotland; it is abundant in the Lower Llandovery of South Wales; but its maximum of development takes place in the May-Hill Sandstones, where it is a marked feature in the fauna. It is sparingly exhibited in the Wenlock shales and sandstones, *Cornulites* having replaced it individually in those beds. *Tentaculites anglicus*, *T. ornatus*, and *T. tenuis* are also Ludlow species; and the long-lived *T. anglicus* either passes to the Middle Devonian slightly modified, or is replaced by Schlotheim's species *T. scalaris*.

The 3 genera and 4 species (*Cornulites serpularius*, *Tentaculites anglicus*, *T. ornatus*, and *Spirorbis Lewisii*) pass to the Wenlock.

The Cephalobranchiate or Tubicolar Annulosa (Annelida) play an important part in the life and distribution of the class through time. Their habits insure persistency, their structure security, and their bathymetrical ranges are such as to lessen their chances of modification through relative changes of land and sea. No form of the order Errantia, or Dorsibranchiate Annelida, has been detected in the Llandovery rocks, although, doubtless, they existed, as many of the so-called fucoidal remains are only tracks of these creatures; and their presence has been demonstrated by Mr. G. J. Hinde through his discovery of the jaws of many species of the Polychæta in the Silurian, Devonian, and Carboniferous formations. In the Wenlock alone he has discovered the remains of 6 genera and 24 species; and in the Ludlow 2 of the same genera and 6 species. No one can doubt that, by careful sifting and preparation, the clays and shales of the still older rocks may yield a rich harvest of the remains of the Annulosa and soft-skinned Echinoderms. This process is now bearing fruit through the energetic measures employed by Mr. G. Maw, in having large quantities of the Wenlock Shales washed, sifted, and examined. Numbers of new forms have been discovered. The same result has been obtained through the determined and persistent search made by Mr. Bennie (the Collector for the Scotch Survey) for remains of the Holothuridæ in the Carboniferous shales of Scotland, and also for the Chitonidæ. The results obtained by this patient worker, and the species collected, are now being described and figured for the Glasgow Geological Society by Mr. Etheridge, Junior.

It is now the age of microscopical investigations, and ere long microscopic palæontology will stand on the same footing with petrological and crystallographic investigations.

Crustacea.—The distribution of some of the species of the Crustacea through the Lower Llandovery is more constant and universal than in any other Silurian deposit. *Calymene Blumenbachii*, *Encrinurus punctatus*, *Illænus Thomsoni*, *Proëtus Stokesii*, and *Phacops Stokesii* occur in almost every locality, and all 5 pass to the Wenlock. 7 of the known 24 species do not pass to any higher horizon than Upper Llandovery; they are *Illænus æmulus*, *I. Bowmanni*, *I. Maccallumi*, *Phacops Weaveri*, *P. obtusicaudatus*, *Lichas laxatus*, and *Trinucleus concentricus*. To show how equally the species are distributed, I may state that in Caermarthenshire 7 genera and 12 species occur; in Pembrokeshire 7 genera and 11 species; in Worcestershire 7 genera and 13 species; in Shropshire 7 genera and 15 species; and in Ireland 7 genera and 14 species; and, singularly also, 7 genera and 14 species pass to the Wenlock. As we have before seen, 10 species are Lower Llandovery and Caradoc—thus, as regards the Crustacea, rendering the value of the Upper Llandovery as a distinct palæontological group more questionable still.

Brachiopoda.—The species in this class are more than double the number of those of any other in the Upper Llandovery rocks. We recognize 65 species and 13 genera. The geographical distribution of *Atrypa* (5 species), *Leptæna* (4), *Orthis* (10), *Pentamerus* (4), *Rhynchonella* (9), *Stricklandinia* (2), *Spirifera* (5), and *Strophomena* (11) is complete through South Wales, Gloucestershire, Worcestershire, and Shropshire. These 8 genera include the mass of species (50 of the 65) that range through the fourteen localities I have selected, and whence I have drawn the materials for analysis, and I believe I have omitted none. *Lingula* with 5 species, *Crania* and *Discina* each with 1, *Chonetes* with 3, and *Meristella* with 6 species are sparingly and irregularly distributed; but we should expect this from the habits and habitats of 3 at least of the genera. No less than 36 species come up from the Lower Llandovery (22 of the same are Caradoc); and 41 of the 65 range into the Wenlock beds. As among the Crustacea, few species belong to the Upper Llandovery proper, showing how slight is the evidence afforded us to separate the Lower and Upper Llandovery. The stratigraphical unconformity is, however, completely borne out by a corresponding palæontological break. This is most decisively seen from the Actinozoa, the Crustacea, the Brachiopoda, and the Lamellibranchiata; indeed Cardiganshire has as yet only yielded 1 species of Actinozoa, *Petraia elongata,* M'Coy. The Upper Llandovery rocks of the nine chief areas given below have yielded the following number of genera and species of Brachiopoda:—

Counties.	Genera.	Species.
Pembrokeshire	11	19
Caermarthenshire	12	38
Cardiganshire	none.	none.
Radnorshire	6	22
Gloucestershire	9	27
Worcestershire	11	35
Shropshire	13	13
Scotland	9	12
Ireland	10	19

No less than 11 genera and 41 species pass up to the Wenlock group, thus showing that a greater number of species in this class pass up than belong to any even of the most prolific areas.

Lamellibranchiata.—Considering the few species known in the Lower Llandovery (3), we have here a marked change in the greatly increased fauna of bivalve Mollusca, which have increased from the 3 genera and 3 species of the Lower Llandovery (*Pterinæa retroflexa*, *Mytilus mytilimeris*, and *Orthonota sulcata*) to 12 genera and 29 species. 2 of the 3 species above named pass to these upper beds, so that the specific fauna is essentially new; in the end, however, it gives to the Wenlock 7 genera and 15 species; or 50 per cent. pass to the Wenlock. The Worcestershire area is most prolific, 12 species occurring. Only 3 species are known in Scotland, *Anodontopsis bulla*, *Pterinæa Sowerbyi*, and *Cardiola striata*, and 3 in Ireland, *Anodontopsis bulla*, M'Coy, *Pterinæa bullata*, M'Coy, and *Ctenodonta subcylindrica*, M'Coy. No species is known either in Radnorshire or Caermarthenshire. (*Vide* Table No. XII.)

Gasteropoda.—Equally balanced with the above group, the distributional value being through species of *Holopella*, *Acroculia*, *Rhaphistoma*, and *Turbo*. These species, too, have a wide geographical distribution, Worcestershire, as before, possessing the greatest number of species (9), although here only equal to Ireland, which has also 9 species; while Caermarthenshire has 7, the remainder of the 13 genera and 28 species being equally distributed. 6 genera and 8 species pass to the Wenlock; they are *Acroculia haliotis*, *Euomphalus alatus*, *E. frenatus*, *E. sculptus*, *Holopella obsoleta*, *Loxonema sinuosum*, *Murchisonia articulata*, and *Turbo tritorquatus*. No form occurs in the Upper Llandovery of Cardiganshire.

Pteropoda.—Only 1 species is known in the Upper Llandovery. *Conularia cancellata*, Sandb., occurs in Gloucestershire and Shropshire, and is known in no other formations or localities in Britain. The more abundant *C. Sowerbyi* is Lower Llandovery, Wenlock, and Ludlow. It is questionable if *C. cancellata* is really a British species or only a variety of *C. Sowerbyi*. 7 of the 10 areas have no represesentative of this group.

Heteropoda.—*Ecculiomphalus* (*Cyrtolites*) and *Bellerophon*, the former having 2 species (*E. lævis*, Sby., and *E. scoticus*), the latter 9, range pretty equally through the Upper Llandovery rocks, *B. dilatatus*, *B. trilobatus*, and *B. carinatus* having the widest or most extended geographical distribution. The rarer forms, *Ecculiomphalus scoticus*, M'Coy, *Bellerophon subdecussatus*, M'Coy, *B. wenlockensis* and *B. obtectus*, Phill., have as yet only occurred each in one locality; 5 of the 11 have appeared before in the Caradoc; but only one species, *B. carinatus*, seems to have been Lower Llandovery. These Pelagic Mollusca, especially the family Atlantidæ, have no fixed habitat, their distribution being quite independent of the nature of the sea-bottom, so that the Bellerophons of the Silurian, Devonian, and Carboniferous periods occur indifferently in mechanical deposits of the most varied petrological or lithological characters. The great *Porcellia* (*P. Woodwardii*, Sby.) of the Middle Devonian, or the two species *P. striata* and *P. Symondsii* of Phillips, occur in all sorts of deposits all through the history of the genus, of which 12 or 14 species range from the Devonian to the Trias, Belgium having afforded many forms. Conrad's genus *Cyrtolites*, probably the *Ecculiomphalus* of Buckland, is represented in Britain by 3 species—*E. Bucklandi*, Caradoc only; *E. lævis*, Upper Llandovery, Wenlock, and Ludlow; and *E. scoticus*, Llandeilo, Caradoc, and Upper Llandovery. Of the 11 Upper Llandovery species 6 pass to the Wenlock, 5 being species of *Bellerophon*, and 1 *Ecculiomphalus* (*E. lævis*).

Cephalopoda.—Of the 6 genera occurring in the Upper Llandovery, viz. *Actinoceras*, *Cyrtoceras*, *Lituites*, *Phragmoceras*, *Tretoceras*, and *Orthoceras*, one (*Actinoceras nummularium*) appears for the first time, and the rare forms *Phragmoceras compressum* and *Cyrtoceras approximatum* have but local geographical distribution. The last named is from the Upper Llandovery of Malvern only; *P. compressum* the same, being of doubtful occurrence in the Ludlow rocks. We have seen that the Caradoc rocks of Shropshire have not yielded a single species of Cephalopod; but here, in the Upper Llandovery of the same county, we have 3 genera and 9 species; yet 8 genera and 47 species occur in the Caradoc rocks. This fact, coupled with others to be arrived at through the tables of distribution, tends to show the shallowing of the Caradoc sea and slow elevation of the land through the latter part of the Caradoc period, and the time represented by the deposition of both the Lower and Upper

Llandovery series. 4 genera and 9 species pass to the Wenlock. Ireland has only 2, *Orthoceras coralliforme*, M'Coy, and *O. subgregarium*, M'Coy. Radnorshire has 1 species, *Lituites cornu-arietis*, Sow. Taking South Wales generally, only 6 species are known there, and these represent 4 genera—*Actinoceras* 1 species, *Lituites* 1 species, *Orthoceras* 3 species, and *Tretoceras* 1 species.

The Upper Llandovery rocks of Scotland give us 4 species, 3 *Orthocerata* and 1 *Phragmoceras* (*P. compressum*).

We therefore find that, out of the whole fauna of the Upper Llandovery rocks, numbering 240 species, only 91 are confined to them and do not pass up. The following list shows the special Upper Llandovery fauna :—

Protozoa	2	species.
Actinozoa	10	,,
Echinodermata	3	,,
Crustacea	8	,,
Bryozoa	3	,,
Brachiopoda	22	,,
Lamellibranchiata	11	,,
Gasteropoda	17	,,
Pteropoda	1	,,
Heteropoda	5	,,
Cephalopoda	9	,,
	91	

Wenlock.

I have stated that 58 genera and 125 species are common to the Wenlock rocks and the Upper Llandovery; in other words, these 125 species pass up from the Llandovery to the Wenlock formation. Next to the Caradoc and Bala, the Wenlock group, embracing the Tarannon Shales, Denbighshire Grits, and Woolhope beds, possesses the largest Silurian fauna known; it numbers 168 genera and 530 species. Eight chief groups or classes out of the fourteen furnish the majority of the species, in each case attaining their maximum in the Wenlock Limestone. They are the following :—

1. Hydrozoa	6	genera and	30	species.
2. Actinozoa	25	,,	76	,,
3. Echinodermata	28	genera and	68	species.
4. Crustacea	27	,,	78	,,
5. Brachiopoda	21	,,	101	,,
6. Lamellibranchiata	16	,,	45	,,
7. Gasteropoda	9	,,	27	,,
8. Cephalopoda	5	,,	30	,,

I may add the Bryozoa, for at no period in the history of the

TABLE XII.—*Upper Llandovery.*

From Lower Llandovery.	Classes.	Genera.	Species.	Geographical Distribution.											Pass to Wenlock.
				Pembrokeshire.	Caermarthenshire.	Cardiganshire.	Radnorshire.	S. Wales generally.	Gloucestershire.	Worcestershire.	Shropshire.	Lancashire, Coniston †.	Scotland.	Ireland.	
	Plantæ	1	1	...	...	...	...	...	...	1/1					
	Protozoa	2	2	...	...	...	...	...	...	1/1	...	...	1/1		
3/15	Hydrozoa	4	33 *	...	...	...	...	...	...	...	...	6/25	4/30	2/6	
9/20	Actinozoa	16	32	3/4	5/12	1/1	3/3	10/14	6/10	7/18	4/9	...	7/10	6/10	14/22
	Echinodermata...............	5	5	2/2	...	...	1/1	2/2	1/1	2/2	...	...	...	1/7	2/2
2/2	Annelida	3	4	3/3	...	...	1/1	3/3	3/3	3/3	3/3	...	...	1/1	3/4
8/10	Crustacea	11	24	7/11	7/12	...	6/8	7/13	6/8	7/13	7/15	...	6/7	7/14	7/14
2/3	Bryozoa........................	2	7	...	2/3	...	...	2/4	3/3	1/1	1/2	...	1/1	...	3/5
10/38	Brachiopoda..................	13	65	11/19	12/38	...	6/22	12/45	9/27	11/35	13/13	...	9/12	10/19	11/41
2/2	Lamellibranchiata	12	29	5/7	4/4	...	...	4/5	5/6	7/12	4/6	...	1/1	3/3	7/15
6/8	Gasteropoda..................	13	28	4/5	7/7	...	3/3	9/11	3/6	4/9	4/5	...	3/4	5/8	6/8
	Pteropoda.....................	1	1	...	...	...	...	...	1/1	...	1/1				
2/2	Heteropoda	2	11	1/3	1/7	...	1/1	1/3	1/1	1/3	1/7	...	1/4	1/1	2/6
1/4	Cephalopoda	6	19	2/4	4/7	...	1/1	4/6	3/4	3/5	3/9	...	2/4	1/2	4/9
45/104	....	91	261	38/58	42/90	1/1	22/40	54/106	41/70	48/103	41/70	6/25	35/74	37/71	59/126

* It is difficult to decide with regard to these species which are Upper and which Lower Llandovery.

† I also give these 6 genera and 25 species in the Upper Llandovery as well as the Lower, for I really know not whose view to adopt as to their stratigraphical position. Mr. Aveline and Prof. Hughes place them in the Tarannon Shales, Mr. Lapworth and Dr. Nicholson in the Lower Llandovery.

Lower Palæozoic rocks were they so largely represented, and all the known forms in the Wenlock group (11 genera and 24 species) occur in the Wenlock Limestone and Shale, and in those of England alone, only 1 species occurring either in Scotland or Ireland.

Protozoa.—*Cliona prisca* and *Spongarium Edwardsii* are both Denbighshire-grit species, the latter being also Wenlock and Ludlow; *Cnemidium tenue* occurs in the Wenlock only, and *Ischadites Grindrodi* in the Woolhope; the other well-known species, *I. Kœnigi*, Murch., has a wider range both in time and space, and has occurred in the Wenlock rocks beneath the Cretaceous series at Ware, in Herefordshire, in the Silurian cores brought up from a depth of 1000 feet, during trials for the better supply of London with water. 30 Wenlock species were obtained here from a few feet of cores; they are identical with the Wenlock species of Dudley and Wenlock Edge. (*Vide* page 229, in the Chapter upon the extension of the older rocks under the London area.) The singular and still doubtful genus *Stromatopora* (*S. striatella*) occurs plentifully in the shales and limestones of the true Wenlock beds, and is also found in the Aymestry Limestone. This genus comprises a large number of Silurian and Devonian fossils of every size and form. The affinity of the Stromatoporids is still doubtful; by some authors they are placed with the Hydrozoa, in the subclass "Hydrocorallina." The doubtful Devonian genus *Caunopora* suggests much research, both from its abundance and peculiar structure. In Britain *Stromatopora* first appears in the Caradoc and Bala group, ranging upwards into the Middle Devonian of Devonshire.

Hydrozoa.—The Wenlock rocks (assuming the Tarannon and Denbighshire beds to be at their base) have yielded 6 genera and 30 species. Stratigraphically they occur chiefly in the Tarannon beds, or probably the Denbighshire Grits. So far as I know there are none in the Woolhope beds, and I omit them from the column headed Wenlock, as they occur chiefly at Builth and in North Wales, and in this case would be repeated. The Tarannon or Denbighshire beds have yielded 5 genera and 23 species; North Wales 1 genus (*Monograptus*) and 8 species; South Wales 3 genera and 15 species; Westmoreland 3 genera and 16 species; Scotland 3 genera and 5 species.

Actinozoa.—At no period during the progress of Palæozoic time was there so large and rich a Coralliferous fauna as during the Wenlock period; numerically the Middle Devonian about equalled the Wenlock species in number, the genera and species being in both deposits much the same. The Wenlock rocks of Britain yield 25 genera and 76 species, the Devonian 24 genera and 52 species, and the Carboniferous 36 genera and 141 species.

I believe every known Wenlock species (there are 76 of them) occurs in the Wenlock Limestone and its subordinate shales. In the lower division, especially the Tarannon Shale and the Denbighshire Grits, the species are few, not more than five being known in the former and four in the latter.

The Tarannon species are *Favosites asper*, *F. fibrosus*, *F. gothlandicus*, *Petraia bina*, and *P. subduplicata*. The four Denbighshire-grit species are also *Favosites aspera* and *F. fibrosus*, *Petraia subduplicata* and *Syringopora serpens*. The upper member of the Lower Wenlock (the Woolhope beds) yields 16 genera and 26 species, most equally distributed generically. The North-Welsh Wenlocks yield 7 genera and 11 species, and the South-Wales beds 10 genera and 18 species; Scotland 8 genera and 11 species; and Ireland 14 genera and 23 species.

We must not forget that 14 genera and 22 species came from the Llandovery rocks, and 18 pass to the Ludlow group, 13 of which were also Llandovery; thus 41 species are peculiarly Wenlock.

Echinodermata.—As compared with the Upper Llandovery, with only 5 genera and 5 species, and the Lower Llandovery only 2 species, the Wenlock sea must have been highly favourable to the development of the Echinodermata; no greater development of life is known in any formation, for 60 of the 68 known species of Echinodermata were new appearances in the British area. Many are American; 65 of the 68 are Wenlock Limestone; no species is known in Scotland, and only 1 in Ireland (*Actinocrinus Wynnei*, Baily); only 1 species occurs in N. Wales in the Tarannon Shale (*Actinocrinus pulcher*), and only 2 in the Woolhope (*Eucalyptocrinus polydactylus*, M'Coy, and *Pisocrinus pilula*, De Kon.).

We should expect that out of so large a fauna many species would pass to the higher divisions of the Upper Silurian, but only 4 genera and 6 species pass to the Lower Ludlow. These are of the Crinoidea, *Actinocrinus pulcher*, *Ichthyocrinus pyriformis*, and *Ichthyocrinus M'Coyanus*; of the Cystidea, *Pseudocrinites magnificus*, *P. quadrifasciatus*; and of the Asteroidea, *Rhophalocoma pyrotechnica*. *Ichthyocrinus pyriformis* is the only species occurring in the Aymestry Limestone; the Upper Ludlow only holds 1 species in common with the Wenlock, the long-lived *Actinocrinus pulcher*. No less than 20 new Echinodermal genera made their appearance in the Wenlock sea, and 17 of them are confined to the Wenlock rocks; the 4 genera that pass to the Ludlow are *Ichthyocrinus*, *Taxocrinus*, *Pseudocrinites*, and *Rhophalocoma*. This marked, sudden, and important addition to the 3 orders of the Echinodermata can only be explained upon the theory of migration from some prolific area; whence it is most difficult to suggest; but looking at the great generic and specific development of the Crinoidea, Cystidea, &c. in N. America, and the great resemblance, if not identity, of the faunas in the two areas, would lead one to surmise that it was from the west rather than from Europe that the Wenlock sea derived these Echinodermata.

Annelida.—No other British Palæozoic strata possess so many species of Annelida; they number 35. The Upper Llandovery possesses only 4 species, the Lower Llandovery 3, the Caradoc 16, the Llandeilo 3, and Ludlow 17 species.

This exuberance in the Wenlock strata is due to the researches of one naturalist*, through whose careful investigations no less than 6 new genera and 24 new species have been added to the Annelidan group of the Wenlock. We know of but one Wenlock species in Scotland or Ireland. All except one species occurs in the true Wenlock Limestone and shales: 4 species pass to the Lower Ludlow (*Helminthites*, sp., *Serpulites dispar*, *S. longissimus*, and *Spirorbis Lewisii*) and 8 to the Upper (viz. *Cornulites serpularius*, *Serpulites dispar*, *S. longissimus*, *Tentaculites anglicus*, *T. ornatus*, *Trachyderma squamosa*, and 2 species of *Arabellites*).

Crustacea.—Ten new genera appear here for the first time; it is important to name them—*Turrilepas*, *Æchmina*, *Cyphaspis*, *Deiphon*, *Eurypterus*, *Hemiaspis*, *Pterygotus*, *Thlipsura*, *Cythere*, and *Cytherellina*. The entire Crustacean fauna consists of 27 genera and 78 species; the Upper Llandovery transmits to it 7 genera and 14 species: 74 of the 78 species occur in the Wenlock Limestone; and the 4 wanting species are *Homalonotus cylindricus*, *Ceratiocaris ludensis*, *Primitia excavata*, and *P. lenticularis*. The Woolhope beds hold a remarkable Crustacean fauna, comprising 13 genera and 24 species: this class and the Brachiopoda are the only two marked zoological groups in this division of the Lower Wenlock series; 12 of the Trilobita are Upper Llandovery, and only 1 is distinctly a Woolhope species, viz. *Homalonotus cylindricus*, Salt. The remaining 3 species of Crustacea in the Woolhope are *Primitia excavata*, *P. lenticularis*, and *Cythere Grindrodiana*, Salt., all belonging to the Ostracoda; they are of no value. We thus rather unexpectedly find that the Woolhope formation possesses groups of fossils almost equal to those of the Wenlock Limestone; such as the Actinozoa with 26 species, 18 of which are also Upper Llandovery; the Crustacea with 24 species, 19 of which are Trilobites; the Brachiopoda with 17 genera and 56 species out of the 21 genera and 96 species known in the Wenlock Limestone. The poverty of the Crustacea in the Tarannon and Denbighshire Grits might be expected from the lithological characters of the rocks; only 8 of the 78 species occur in the former, and 5 in the latter horizon. North Wales has only yielded 5 genera and 11 species, and South Wales 9 genera and 14 species; only 3 species occur in Scotland—*Turrilepas Wrightianus*, *Beyrichia Klœdeni*, and *Phacops Stokesii*. The Irish species number 8—*Calymene Blumenbachii*, var. *Allportiana*, *Cheirurus bimucronatus*, *Encrinurus punctatus*, *E. variolaris*, *Phacops caudatus*, *P. nudus*, *P. Stokesii*, and *Proëtus latifrons*. The order Merostomata makes its first appearance in the Wenlock through *Eurypterus punctatus*, *Hemiaspis horridus*, and *Pterygotus problematicus*, all in the Wenlock-Limestone series. This group of Crustacea has been extensively and critically worked out and illustrated in a masterly manner by Dr. H. Woodward, F.R.S., in the volumes of the Palæontographical Society, the Quarterly Journal of the Geological Society, and the 'Geological Magazine.' The suborder Eurypterida is repre-

* G. J. Hinde, Quart. Journ. Geol. Soc. vol. xxxvi. pp. 368–378.

sented by 5 genera, 3 of which commence or first appear in this division of the Upper Silurian strata. No less than 12 species of *Primitia*, besides other Ostracods, have been determined by Prof. Rupert Jones, F.R.S., two of them being Woolhope (*Cythere Grindrodiana* and *Primitia lenticularis*). Of the whole group of Crustacea, 13 genera and 18 species pass up to the Lower Ludlow, whose Crustacean fauna numbers 18 genera and 47 species.

Bryozoa.—Of the 11 known genera that occur, 6 are new in the Wenlock. No less than 24 species are known in the shales and limestones; none have occurred in the Tarannon Shales, Denbighshire Grits, or anywhere in North Wales or Scotland. In South Wales 2 species are known, *Diastopora consimilis*, Lonsd., and *Ptilodictya lanceolata*; the same species occur in Ireland, and, with *Escharina angularis*, Lonsd., pass to the Lower Ludlow. *Fenestella assimilis*, *F. subantiqua*, and *Ptilodictya lanceolata* were also Lower Llandovery species. The 6 genera not known in the older rocks, and which first appear in the Wenlock, are *Cellepora*, *Ceriopora*, *Diastopora*, *Discopora*, *Escharina*, and *Polypora*.

Most of the Palæozoic genera belong to the order Gymnolæmata, suborder Cyclostomata. We know of no Palæozoic genera extending into the Secondary Period, where this class attains its maximum palæontological development, the Cretaceous system alone having yielded more than 200 species.

Brachiopoda.—In the Wenlock rocks, like the Caradoc, the Brachiopoda greatly predominate over most of the other groups. We have determined 15 genera and 109 species in the Caradoc; and now in the Wenlock are enabled to show that 22 genera and 101 species occur, being an increase of 7 new genera (namely, *Athyris*, *Cyrtia*, *Eichwaldia*, *Nucleospira*, *Obolus*, *Orbiculoidea*, and *Retzia*), the species being fewer so far as we know through the literature of the class. 21 genera and 96 of the 101 species belong to the Upper Wenlock or Wenlock Limestone and shale*; all the known 22 genera are also represented in the same horizon. The Woolhope beds yield 17 genera and 56 species, every Woolhope shell being also Wenlock. *Orthis mullochensis*, Dav., or its variety *O. reversa*, may stand alone as a Woolhope species, but every other form is equally Wenlock. Certain horizons in the Wenlock rocks are richer generically and poorer in species than others; this is shown in the Tarannon Shales and Denbighshire Grits, where, in the former, 10 genera occur with only 15 species; it is the same with the Denbighshire Grits, in which we have 14 genera and only 19 species. No genus or species is peculiar to either the Tarannon or Denbighshire beds; all are good Upper Wenlock forms. Those species having the longest range in time in the Wenlock group number about 11; they also have a correspondingly wide range in space; they are:—

* The researches of Mr. Davidson, F.R.S., upon the collection made by Mr. G. Maw in these beds has enabled him to add many new species and one or two new genera to the fauna of the Wenlock rocks.

Atrypa reticulata.	Rhynchonella nucula.
Chonetes striatellus.	Spirifera elevata.
Crania implicata.	—— exporrecta.
Leptæna transversalis.	Strophomena pecten.
Meristella tumida.	—— rhomboidalis.
Orthis elegantula.	

All those named have appeared in the Llandovery or Caradoc before, and all pass to the Ludlow; but their universality through the Wenlock renders them conspicuous or long-lived, though not perhaps the best witnesses in determining the age of any particular horizon through the Wenlock deposits; those species which are short-ranged, or essentially typical or confined to particular beds, should be named, as contradistinguished from those given above. No species is peculiar to the Tarannon Shale, although 10 genera and 15 species range through this series of beds. No species essentially marks, distinguishes, or is confined to the Denbighshire Grits; yet 14 genera and 19 species also occur in this horizon.

Although 17 genera and 56 species are known in the Woolhope beds, yet only 2 species are restricted to them; these are *Orthis mullochensis*, Dav., and *Pentamerus undatus*, Sby. This last species occurs in the Woolhope (?) of Ireland.

Every Tarannon species except *Lingula Symondsii* had previously occurred, or appeared in one or other of the two Llandovery horizons or in the Caradoc. All the species in the Denbighshire Grits except three, *Discina Morrisii*, *Meristella tumida*, and *Rhynchonella navicula*, also have appeared in and passed up from the same deposits. Thus we find that the restricted Brachiopodal fauna (so far as we at present know) in these beds at the base of the Wenlock is extremely scanty.

Out of the 101 known Wenlock species, 56 had not occurred in any earlier formation, but first appeared in the Woolhope and Wenlock Limestone; these newly introduced Wenlock forms represent 20 genera. I deem it important to name them and give the numbers of the species in each genus; they are:—

Athyris	3 species.	Obolus	3 species.
Atrypa	2 ,,	Orbiculoidea	2 ,,
Crania	3 ,,	Orthis	6 ,,
Cyrtia	1 ,,	Pentamerus	3 ,,
Discina	4 ,,	Retzia	2 ,,
Eichwaldia	1 ,,	Rhynchonella	4 ,,
Leptæna	2 ,,	Siphonotreta	1 ,,
Lingula	2 ,,	Spirifera	3 ,,
Meristella	4 ,,	Strophomena	8 ,,
Nucleospira	1 ,,	Triplesia	1 ,,

Out of so large a fauna as 101 species, 96 of which occur in one division (the Wenlock Limestone and Shale), we should expect to find a large proportion absolutely restricted to that horizon. Of such restricted species in the true Wenlock rocks (limestones and shales) we have 24 or 25 per cent. None of the following species occurs in any other horizon; and they may therefore be accepted as definitely typical Wenlock species—*Atrypa Barrandii*, Dav., *Crania Grayii*, Dav., *C. Sedgwickii*, Lewis, *C. siluriense*, Dav., *Cyrtia nasuta*, Lewis, *Leptæna segmentum*, Ang., *Meristella nitida*, Hall, *Nucleospira pisum*, Sow., *Obolus Davidsoni*, Salt., *Orbiculoidea Becketiana*, Dav., *Orthis æquivalvis*, Dav., *O. basalis*, Dalm., *O. Lewisii*, Dav., *O. Hughesii*, Dav., *Retzia Salteri*, Dav., *Siphonotreta anglica*, Mor., *Spirifera sulcata*, His., *Strophomena Dayi*, Dav., *S. Fletcheri*, Dav., *S. Hendersoni*, Dav., *S. Orbignyi*, Dav., *S. Walmstedti*, Linds., *S. Waltoni*, Dav., and *Triplesia MacCoyana*, Dav.

The Wenlock Brachiopoda of Scotland number 11 genera and 20 species, most of them belonging to the long-range species, the more restricted being *Meristella Maclareni*, Hasw., *Nucleospira pisum*, Sow., *Orthis Lewisii*, Dav., *O. wenlockensis*, Dav., *O. polygramma*, Sow., and *Strophomena Hendersoni*, Dav.

The Irish Wenlocks contain 14 genera and 31 species; the most important are *Obolus Davidsoni*, Salt., *Pentamerus undatus*, Sow., *Rhynchonella Beltiana*, Dav., *R. deflexa*, Sow., *Orthis rustica*, Sow., *Spirifera bijugosa*, M'Coy, and *Strophomena Dayi*, Dav. The genera numerically rich in species are *Orthis* (16 species), *Rhynchonella* (10), *Spirifera* (8), *Strophomena* (16), *Pentamerus* (6), *Meristella* (5), and *Atrypa* (5). The rarer genera are but feebly represented. 12 genera and 32 species pass to the Lower Ludlow, 10 genera and 20 species appear in the Aymestry, and 11 genera and 17 species in the Upper Ludlow. Again, the Wenlock is allied to the Caradoc and Llandovery groups through 11 genera and 41 species, 39 being Upper Llandovery, 22 Lower Llandovery, and 14 Caradoc species; 5 Llandeilo species lived on through all five periods, viz. *Leptæna sericea*, *Orthis biforata*, *O. calligramma*, *O. elegantula*, and *Strophomena rhomboidalis*.

Lamellibranchiata.—Out of the 16 genera and 44 species of bivalve shells ranging through the Wenlock rocks, the upper division or Wenlock Limestone yields 43 species, the one absent or uncertain form being doubtfully *Lunulacardium aliforme*, Sby.

The Tarannon Shale contains, so far as we know, only 2 species, and both are Upper Llandovery shells, *Pterinæa planulata*, Conrad, and *P. retroflexa*, Wahl.; both pass to the Ludlow beds. The Denbighshire Grits from all available sources yield 7 genera and 10 species. The Woolhope only 3 genera and 5 species: these, with the Denbighshire-grit species, are all Upper Wenlock also. The local stratigraphical position of the "Woolhope or Barr" Limestone carries with it occasionally a peculiar fauna, and, although strictly of Wenlock age, there is always uncertainty as to the occurrence of few or many species, but it is next in numerical value to the Upper Wenlock. The Wenlock rocks of North Wales furnish 8 genera and 14 species, *Pterinæa*, *Cardiola*, and *Cucullella* being the chief genera. *Pterinæa* has yielded 6 species, *Cardiola* 3, and *Cucullella*

3: other genera (*Avicula*, *Arca*, &c.) only one or two species each.

In South Wales 11 genera and 26 species have been collected. The genera are the same, but with specific additions to *Modiolopsis* and *Mytilus*.

Of the 3 Irish genera the 6 species are—*Pterinæa lineata*, Goldf., *P. planulata*, Conr., and *P. retroflexa*, Wahl., *Cardiola fibrosa*, Sow., and *C. interrupta*, Brod., with *Goniophora cymbæformis*, Sow.; none are confined to the Irish beds. Only 5 genera and 8 species of Lamellibranchiata are really peculiar to the Wenlock series. 7 genera and 15 species came in from the Upper Llandovery; 3 of these 15 are Lower Llandovery also, viz. *Pterinæa retroflexa*, *Cardiola interrupta*, and *Mytilus mytilimeris*; 2 of the same are Caradoc, and 3 species came direct from the Caradoc; they are *Pterinæa tenuistriata*, M'Coy, *Arca* (*Palæarca*) *edmondiiformis*, M'Coy, and *Ctenodonta anglica*, D'Orb. Thus the Wenlock is united to the Upper Llandovery below through 17 species, and to the Lower Ludlow above by 21 species, and these all pass to the Upper Ludlow, so that the actual number of peculiar Lamellibranchs, or the Bivalve fauna, is reduced to the following 8 species:—*Ambonychia tumida*, Sollas, *Pterinæa asperula*, M'Coy, and *P. laminosa*, Goldf., *Cleidophorus planulatus*, Conr., *Modiolopsis acutipora*, Sollas, *M. inflata*, var., and *M. chemungensis*?, Conr., with *Mytilus unguiculatus*, Salt. Nevertheless, assuming that the transgressional species also strictly belong to the rocks in which they occur, the Wenlock Bivalve fauna consists of 25 species by retaining those forms that pass up to the Ludlow.

Gasteropoda.—Looking at the splendid Cœlenterate, Echinodermal, Crustacean, and Brachiopodal faunas in the Wenlock series, the distribution and ranges of which we have analyzed and tabulated, we should have expected this class to have been more largely represented, especially as during the Caradoc and Upper Llandovery periods a larger molluscan fauna existed, although apparently the nature of the sea-bed was not so favourable as that of the more calcareous and argillaceous condition of the Upper Wenlock, in which the great mass of the Wenlock fauna occurs. All the genera belong to the order Prosobranchiata and division Holostomata. The Caradoc Gasteropoda, as we have seen, number 14 genera and 53 species, the Wenlock 9 genera and 27 species; the 9 genera represent 5 families. One species only occurs in the Tarannon Shale (*Acroculia haliotis*), and ranges through to the Wenlock Limestone and Ludlow. The Denbighshire Grits contain *Acroculia haliotis*, *Holopella gracilior*, *Loxonema elegans*, *Murchisonia articulata*, and *M. Lloydi*, or 4 genera and 5 species. The Woolhope exhibits but a small fauna, only 8 species, 4 of which are *Euomphali* and 2 *Acroculiæ*, with *Trochus* (*Cyclonema*) *exaltatus* and *Turbo tritorquatus*. In this, as in all the other classes, nearly every species known occurs in the Upper Wenlock; thus the 9 known genera and 24 out of the 27 species belong to that horizon. 7 genera and 17 species occur in South Wales, but only 1 in Scotland

(*Euomphalus furcatus*). Ireland yields 4 genera and 5 species (*Murchisonia articulata*, *M. Lloydii*, *Euomphalus alatus*, *Cyclonema corallii*, and *Acroculia haliotis*). We must remember that 5 genera and 6 species range from the Upper Llandovery; these are *Euomphalus alatus*, Sow., *E. furcatus*, Sow., *E. sculptus*, Sow., *Holopella obsoleta*, *Loxonema sinuosa*, Sow., and *Murchisonia articulata*, Sow., 2 of the same occurring in the Caradoc, namely—*Euomphalus alatus*, Sow., *E. sculptus*, Sow., and probably *Turbo tritorquatus*, M'Coy; and 5 of these same 6 range to the Ludlow. Only 17 species out of the 27 strictly belong to the Wenlock rocks proper. At present we know of no species other than those in the division Holostomata in the Silurian rocks. *Eunema* is the only new genus that appeared in this formation; *E. cirrhosum* is a South-Wales species.

Pteropoda.—Only 3 species, *Conularia Sowerbyii*, Defr., *Theca anceps*, Salt., and *T. Forbesii*, Sharpe, have as yet appeared in the Wenlock group; none of the 3 occurs in the Tarannon Shale, in the Woolhope beds, or in Ireland. *Theca Forbesii* has been found in the Denbighshire Grits and Wenlock Limestone, and passes upwards to the Upper Ludlow. *T. anceps* is here Wenlock only, but is a Caradoc species also. *Conularia Sowerbyi* first appeared in the Caradoc, and, with the exception of the Upper Llandovery, is present in all horizons up to the top of the Upper Ludlow; it also occurs in the Scotch beds. The only form of Thecosomatous Pteropod that transgresses the Silurian rocks is *Conularia*, which is Devonian and Carboniferous; but in Britain *Conularia* has not occurred in the Devonian series, although its associate, *Bellerophon*, is represented by 5 British Devonian forms, 2 occurring in the Lower, 1 in the Middle, and 4 in the Upper Devonian. *Conularia Sowerbyi* and *Theca Forbesii* both pass to the Upper Ludlow.

Heteropoda.—This pelagic order is well represented in the Wenlock beds through *Ecculiomphalus lævis* and 7 species of *Bellerophon*; but no species is confined to or specifically characteristic of the Wenlock beds. All had previously occurred either in the Caradoc or Llandovery rocks. *Ecculiomphalus lævis*, *Bellerophon trilobatus*, and *B. carinatus* range into the Upper Ludlow beds; none occurs in the Tarannon Shale; 3 species are known in the Denbighshire Grits (*Bellerophon trilobatus*, *B. expansus*, and *B. carinatus*), and 3 in the Woolhope beds (*B. bilobatus*, *B. dilatatus*, and *B. trilobatus*). In the Wenlock Limestone we know of 4 species of *Bellerophon* and *Ecculiomphalus lævis*. *B. dilatatus* is the only form known in Ireland; and Scotland yields none. The 3 species passing up or ranging into the Ludlow series are *Ecculiomphalus lævis*, *Bellerophon trilobatus*, and *B. subdecussatus*; there are none in the Aymestry Limestone.

Cephalopoda.—5 genera and 30 species of the order Tetrabranchiata, illustrating the Nautilidæ and Orthoceratidæ, are known in the Wenlock rocks: all but 3 species are represented in the Wenlock Limestone and Shale; these 3 are Woolhope species (*Actinoceras baccatum*, H. Woodw., *Lituites cornu-arietis*, Sow., and *Orthoceras conicum*, Sow.). *Actinoceras baccatum* is essentially a Woolhope species, described by Dr. H. Woodward, and the only one known from the Woolhope beds of Little Hope. *Lituites cornu-arietis*, Sow., and *Orthoceras conicum*, Sow., although not ranging higher than the Woolhope beds, appeared in the Llandovery, and help to connect the Lower Wenlock with the Upper and Lower Llandovery. In the Denbighshire Grits we have almost unexpectedly 3 genera and 7 species, only 2 of which are of Llandovery age (*Orthoceras tenuicinctum*, Portl., and *O. subgregarium*, M'Coy). The remaining 5 species pass from the Denbighshire rocks, where they are first known, to the Upper Wenlock; they are *O. primævum*, Forbes, *O. tracheale*, Sow., *O. ventricosum*, *Phragmoceras nautileum*, and *Cyrtoceras ibex*. 26 of the 30 species occur in the Wenlock Limestone and Shale; 13 range through South Wales, and 12 through North Wales, 7 belonging equally to North and South Wales. The only 3 Irish species known are *Orthoceras* (*Creseis*) *primævum*, Forbes, *O. subundulatum*, Portl., and *O. tenuicinctum*, Portl.; and the 3 Scotch forms are *O. Maclareni*, Salt., *O. subundulatum*, Portl., and *O. tenuicinctum*, Portl. 11 species pass to the Lower Ludlow; 2 of these, and the only 2 known (*Lituites giganteus*, Sow., and *Orthoceras angulatum*, Wahl.), pass to the Aymestry Limestone; and 3 genera and 8 species range to the Upper Ludlow; thus only 4 genera and 9 species out of the 30 are really Llandovery, or these 9 species come up from the Llandovery and Caradoc.

The accompanying Table shows the numerical history of the 14 classes. The first four columns illustrate the stratigraphical distribution of the species through the Tarannon beds, Denbighshire Grits, Woolhope beds, Wenlock Shales and Limestone, indeed all the formations above the Upper Llandovery. The succeeding five columns show the geographical distribution of the species through North Wales, South Wales, Westmoreland, Scotland, and Ireland; and to show still further the connexion between the Wenlock and Ludlow fauna, I have stated in the remaining or last three columns the number of species that pass to the three divisions of the Ludlow group, in which it will be seen that out of the 171 genera and 536 Wenlock species, 71 genera and 126 species pass to the Lower Ludlow, 38 genera and 52 species to the Aymestry, and 51 genera and 87 species to the Upper Ludlow; any higher transgression from the Ludlow into the Devonian is given under the Ludlow table. There are only 20 species, including the 6 Fishes from the passage-beds and the 8 species of Merostomata, that range through the Ludlow series. The oldest fish-remains occur in the Lower Ludlow, *Scaphaspis ludensis*, Salt., being the oldest species known.

TABLE XIII.—*Wenlock.*

From Upper Llandovery.	Classes.	Genera.	Species.	Stratigraphical Distribution. Tarannon beds.	Denbighshire Grits.	Woolhope beds.	Wenlock beds*.	Geographical Distribution. North Wales.	South Wales.	Westmoreland.	Scotland.	Ireland.	Pass to Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
	Plantæ.														
	Protozoa	5	6	...	2/2	1/1	3/3	1/1	1/1	...	1/1	...	3/3	2/2	2/2
	Hydrozoa	6	36	5/23	...	...	...	1/8	3/15	3/16	3/5	1/1	1/2		
14/22	Actinozoa	25	76	2/5	2/3	16/26	25/76	7/11	10/18	...	8/11	14/23	9/16	7/8	4/7
2/2	Echinodermata........................	28	68	...	1/1	2/2	28/65	1/1	4/5	...	...	1/7	4/6	1/1	2/2
3/3	Annelida	13	35	...	1/1	3/3	13/34	4/4	4/6	...	...	...	3/4	3/3	4/6
7/14	Crustacea	27	78	6/8	3/5	14/25	27/74	5/11	9/14	...	3/3	5/8	13/18	5/6	8/10
3/5	Bryozoa	11	24	...	...	3/4	10/24	...	2/2	...	...	1/1	2/2	1/1	
11/41	Brachiopoda	22	101	10/15	14/19	17/56	21/96	9/23	12/39	...	11/20	14/31	12/32	10/20	11/17
7/15	Lamellibranchiata	16	44	1/2	7/10	3/5	15/43	8/14	11/26	...	?	3/6	13/21	3/3	9/24
5/8	Gasteropoda........................	9	27	1/1	4/5	4/8	9/24	5/8	7/17	...	1/1	4/5	6/9	4/6	4/6
	Pteropoda	2	3	...	1/1	...	3/3	1/1	1/1	...	1/1	...	......	......	2/2
2/6	Heteropoda	2	8	...	1/3	1/3	2/5	1/4	1/3	...	...	1/1	2/3	......	2/3
4/9	Cephalopoda........................	5	30	...	3/7	3/4	5/26	4/12	3/13	...	1/3	1/3	3/11	2/2	3/8
58/125	....	171	536	25/54	39/57	67/137	161/473	47/98	68/160	3/16	29/45	45/86	71/126	38/52	51/87

* In the column headed Wenlock beds I omit the Rhabdophora; they appear in the localities.

Ludlow.

392 species, representing 137 genera, is, as nearly as can be ascertained, the numerical value of the Ludlow fauna. No true Ludlow rocks are certainly known to occur in North Wales, excepting perhaps in a small part of Montgomeryshire, south-east of Newtown. The Ludlow formation is zoologically allied to the Wenlock through 129 species. The chief classes, or those most represented numerically, are the Actinozoa with 12 genera and 17 species, the Echinodermata with 12 genera and 21 species, the Crustacea with 29 genera and 97 species, the Brachiopoda with 13 genera and 48 species, the Lamellibranchiata with 17 genera and 71 species, the Gasteropoda with 9 genera and 33 species, the Cephalopoda 6 genera and 37 species, and lastly the Vertebrata, which first appear through the Fishes, represented by 10 genera and 14 species, omitting the genus *Onchus*, the remains of which may be "telsons" or tail-spines of Crustacea. The comparatively small fauna of the Aymestry Limestone (53 genera and 84 species) is, although local, a remarkable one, and clearly shows the nature of the sea-bed and sedimentary material in relation to the habits of life of the species represented. Mostly it is a recurrent fauna from the Wenlock, 57 species being common to the two, these 57 representing 38 genera, clearly showing the rarity and paucity of species illustrating the genera, and the lenticular or accidental nature of the Aymestry Limestone between the Lower and Upper Ludlow beds. The classes that appear to be most fully represented are the Cœlenterata (Actinozoa), the Crustacea, Brachiopoda, Gasteropoda, and Cephalopoda. No fish-remains are known, although the two Ludlow series contain them *. The feeble representation of the Ludlow rocks in North Wales, as before stated (only 19 species), by comparison with Westmoreland (127) calls for critical examination into the physical rather than the palæontological aspect of the question; and this is still more prominently seen through the still larger fauna in South Wales and Shropshire, the former yielding 163 species, the latter 187; and further through the intermediate areas termed Herefordshire (where 114 species are known) and Worcestershire (121). Could we but see and examine the continuity of the old Wenlock and Ludlow sea-bed and its deposits between Denbighshire, Westmoreland, and the south of Scotland, now under the St.-George's Channel (or denuded away), we should doubtless find traces of the Lower Wenlock and Ludlow rocks, uniting the two now disunited areas. We cannot doubt that this continuity once existed, though probably the rocks of the two areas were deposited under very different and local conditions. Petrologically they essentially differ; but palæontologically or specifically in certain groups the agreement is close and decisive, omitting the largely represented Annulose or Crustacean orders Meros-

* Mr. Salter included the Aymestry Limestone with the Lower Ludlow, as being a calcareous condition of it. Mr. Lightbody was always impressed with the fact that the calcareous nature of the beds above the Aymestry Limestone influenced the fossils to a marked degree.

tomata and Phyllopoda in the Ludlow rocks (45 species), which stand alone as a peculiar and local group; their presence therefore need not enter into the calculation *. The great extension of the Wenlock promontory to Wellington, running parallel to the Dudley beds, and the overlap and cover of the Triassic rocks to the north on to the Mersey, Liverpool Bay, Lancaster and Morecambe Bays, go far to lead us to believe that the missing evidence of the agreement between the Ludlow of the two areas of Wales and Westmoreland, as well as the unsatisfactory correlation of the Denbighshire Grits and Tarannon Shales with the rocks of the Lake country, can be accounted for; for it must be admitted that much has yet to be done with these Lower Wenlock rocks of Denbighshire, Westmoreland, &c. The Kendal group (or the Ludlow rocks) and the Ireleth Slates, which are the equivalents of the Wenlock of the south, can certainly be correlated palæontologically, dissimilar as they appear physically. The Scotch uppermost Silurians are exhibited only in three localities; to the south of Kirkcudbright and in the Pentland Hills both the Wenlock and Ludlow groups occur. The American series termed the Lower Helderberg group are the true equivalents of our Lower and Upper Ludlow, and contain a number of species in common. The exact equivalent of the Oriskany Sandstones may be our lowest Devonian. In North America their place is either at the top of the Upper Ludlow or between that and the lowest Devonian rocks, or "Corniferous beds" of the American geologists. I now attempt to analyze the extensive fauna of the Ludlow group, accepting the triple division unconditionally; or, in other words, retaining the Aymestry Limestone as a distinct subformation, not attached either to the Lower or the Upper Ludlow; its accidental position carries with it certain fossils having an important bearing upon physical geology.

Plantæ.—For the first time above the Wenlock we meet with what may be termed plants proper; yet the two genera *Chondrites* and *Fucoides* are doubtful. 5 genera and 5 species are known; 4 species occur in the Upper Ludlow, and 3 of the same in the passage-beds between the Upper Ludlow and Lower Old Red Sandstone; none are known in the Lower Ludlow or the Aymestry beds; nowhere in the Ludlow of either South or North Wales, Westmoreland, or Ireland are plant-remains known. *Actinophyllum plicatum* occurs in Shropshire and Herefordshire; *Chondrites verisimilis* is an Upper Ludlow form in Scotland. The seed-like bodies of doubtful affinities (*Pachytheca sphærica*) occur in the tilestones and bone-bed of the uppermost Ludlow of Shropshire, Worcestershire, and Herefordshire. *Actinophyllum* and *Pachytheca* here first occur, and do not pass to the higher formations. The passage-beds contain *Actinophyllum plicatum*, *Chondrites verisimilis*, *Pachytheca sphærica*, and *Pachysporangium pilula*. 15 species of Crustacea, 19 species of Lamellibranchiata, 6 species of Gasteropoda, 4 species of Heteropoda, and 6 species of Fish, or nearly 70 species, illustrate 10 classes

* Phyllopoda (*Ceratiocaris* 14 species), Merostomata (*Eurypterus* 10 species, *Hemiaspis* 6, *Pterygotus* 9, *Slimonia* 3, and *Stylonurus* 3).

in this borderland between the Upper Ludlow and the Old Red Sandstone.

PROTOZOA.—A series of sponges (Calcispongiæ) numbering 7 genera and 10 species occur in the Ludlow rocks, 3 of which are also Wenlock. 6 genera and 8 of the species belong to the Upper Ludlow; *Amphispongia*, *Favospongia*, and *Tetragonis* are new forms, and appear for the first time, and, with *Favospongia Ruthveni*, *Ischadites Kœnigi*, and 4 species of *Spongarium*, die out in the Upper Ludlow. 3 genera and 5 of the species occur in the Ludlow beds of Westmoreland; they are *Favospongia Ruthveni*, *Spongarium æquistriatum*, *S. interlineatum*, *S. interruptum*, and *Tetragonis Danbyi*. The conformable Old Red Sandstone in the Ludlow area, or anywhere along the extended strike and junction of the two formations, contains nothing in common with the Upper Ludlow save a few fish and crustacean remains, all ceasing with the Downton beds and tilestones. The Eurypterids (*Stylonurus megalops* and *Eurypterus pygmæus*) pass to the lower beds of the Old Red Sandstone; but through all the Old Red of South Wales (or the Silurian area) or Gloucestershire or Somersetshire, from its base to its junction with the Lower Carboniferous, nothing has occurred save fragments of *Cephalaspis* and *Holoptychius*, no other class in the animal kingdom being represented.

HYDROZOA.—Only 1 genus and 8 species of this class seem left to bring to a close the history of the Graptolite group of the Hydrozoa. *Monograptus* has 8 species, which are all Lower Ludlow and occur in the Ludlow area. In no region of the globe where the Silurian rocks have been deposited have any species of this class transgressed or passed into higher formations. About 210 species belonging to 30 genera have lived during the Silurian epoch, ranging from the Arenig with 42 species, the Llandeilo 44, Caradoc 38, Lower Llandovery 50, Upper Llandovery 12, Wenlock 23, to the Ludlow with 8, their maximum development being at the commencement of the Lower Silurian of certain systematists. They came into existence with unexampled prodigality and suddenness, but gradually died out as conditions grew less and less favourable for their sustenance and development. America, Bohemia, Scandinavia, Australia, and Britain have all largely possessed the same hydrozoal fauna, illustrating the same or similar deposits. Whether homotaxially or not, most of the same genera have occurred in rocks of the same age as those of the British Islands, and always under the same physical conditions. The labours and researches of Hall, Barrande, Geinitz, Linnarsson, Nicholson, Lapworth, Hopkinson, Carruthers, and M'Coy in this field of zoological history will ever reflect honour on their memory. To Mr. Lapworth graptologists owe much; no other author has given such attention to the Rhabdophora, whether we regard his specific work or that devoted to their history and geological distribution through time, and his philosophical views relative to their affinities, structure, and systematic classification.

ACTINOZOA.—Not a single species out of the 17 occurring in the

Ludlow beds strictly belongs to them or is confined to the Ludlow; all have previously occurred in the Wenlock. 17 species are Lower Ludlow; 8 of the same occur in the Aymestry Limestone, and 7 in the Upper Ludlow, chiefly the *Favosites* (5 species); 13 species occur in Shropshire, 6 in Westmoreland, and 12 in Worcestershire. *Monticulipora papillata* is the only Scotch species known. 6 species occur in Ireland (*Favosites asper*, *F. cristatus*, *F. fibrosus*, *Alveolites Labechii*, *Cyathophyllum truncatum*, and *Monticulipora papillata*); only 1 species is known in North Wales (*Heliolites tubulatus*); and 6 genera and 9 species in South Wales. The accompanying Table, showing their geographical distribution, will be clearer than description, where the species are so irregularly distributed.

Ludlow Species.	South Wales.	North Wales.	Shropshire.	Worcestershire.	Herefordshire.	Westmoreland.	Scotland.	Ireland.
Alveolites Labechii	*	...	*	*	*	...	...	*
Cœnites intertextus	...	...	*					
Cyathaxonia siluriensis	...	...	...	...	...	*		
Cyathophyllum truncatum	...	...	*	...	...	...	...	*
Favosites asper	*	...	*	*	*	...	...	*
—— cristatus	...	...	*	...	...	*	...	*
—— fibrosus	*	...	*	*	...	*	...	*
—— gothlandicus	*	...	*	*	*			
—— Forbesii.								
Fistulipora decipiens.								
Halysites catenularius	*	...	*	*	...	*		
Heliolites interstinctus	*	...	*	*	*	*		
—— tubulatus	...	*	*	*	*			
Monticulipora papillata	*	...	...	*	*	*	*	
Omphyma turbinata	...	...	*	*	*	...	...	*
Patraia bina	*	...	...	*				
Syringopora bifurcata	...	...	*	*				
—— serpens	*	...	*	*				
	9	1	13	12	7	6	1	6

Echinodermata.—This group in the Ludlow comprises 12 genera and 21 species. There are 3 genera and 4 species of Crinoidea (*Actinocrinus pulcher*, *Ichthyocrinus pyriformis*, *I. M'Coyanus*, and *Taxocrinus d'Orbignyi*). Of the remaining 17 species 4 are Cystideans (*Echinocystites pomum*, *E. uva*, *Pseudocrinites magnificus*, and *P. quadrifasciatus*), all Lower Ludlow; and 13 Asteroidea. 2 species of *Palæaster* (*P. Ruthveni* and *P. hirudo*) and *Palæasterina primæva*, with *Protaster Sedgwickii*, occur in the Upper Ludlow of Kendal, Westmoreland. 4 *Palæocomæ* (*P. Colvini*, *P. cygnipes*, *P. Marstoni*, *P. vermiformis*) are all Lower Ludlow from the Leintwardine beds near Ludlow. *Palæodiscus ferox*, *Protaster leptosoma*, *P. Miltoni*, and *P. Sedgwickii* are from the same horizon and locality, as well as *Rhophalocoma pyrotechnica*—Shropshire thus yielding 8 species of Lower Ludlow starfishes and Westmoreland 4 Upper Ludlow. The Lower Ludlow Echinodermata therefore number 11 genera and 19 species, the Upper Ludlow 6 genera and 7 species. None occur in Herefordshire, Scotland, or Ireland. 4 genera and 7 species (3 Crinoidea, 1 Cystidean, and 3 Asteroidea) came from the Wenlock beds. In the Ludlow promontory and all along the line that marks the junction of the Old Red Sandstone with the Upper Ludlow all Silurian life ceased. The slow elevation of that region caused the Silurian Annuloid fauna to dwindle and pass away almost entirely. No vestige of it again appeared in the true Old Red area anywhere; and the want of evidence to show what rocks may be below the Lower Devonian of the Devonshire and Somersetshire areas leaves the question of stratigraphical or zoological continuity one of doubt and in the region of the unknown. Ireland or North Devon may yet solve the problem, for it is here we should expect it. The new Ludlow genera were *Echinocystites*, *Palæasterina*, and *Tetragonis*, none of which leaves any successors behind, none being known either in the Devonian or Carboniferous rocks.

Annelida.—The Annelida are a singular group in the Ludlow rocks; 9 genera and 17 species have been obtained from the several horizons (4), and their geographical distribution is wide also. 15 species occur in the Upper Ludlow; the characteristic *Cornulites serpularius* is the most abundant, occurring at all 4 horizons, and in all localities except Shropshire and Ireland. The Lower Ludlow has yielded *Cornulites serpularius*, *Serpulites dispar*, *S. longissimus*, *Spirorbis Lewisii*, and *Trachyderma squamosa*. The Aymestry Limestone contains 4 species, all of which are also in the Lower Ludlow. 4 of the 17 species are also Wenlock. 3 species of *Ænonites* and 3 species of *Arabellites*, belonging to the order Polychæta, are determined from jaw-remains by Mr. G. J. Hinde*; they are Upper Ludlow, and help to swell the Annelide fauna. 3 species of the order Tubicola occur in the Passage-beds. 9 species range through South Wales, North Wales has 4, Westmoreland 6, Shropshire 5, Worcestershire 7, Herefordshire 4, and Scotland 3; but none, so far as I can ascertain, occur in Ireland.

Crustacea.—The two great orders of the class Crustacea in the Ludlow rocks are the Merostomata and the Phyllopoda. Of the former we know 32 species—*Eurypterus* 10, *Pterygotus* 9, *Himantopterus* 1, *Slimona* 3, *Stylonurus* 3, and *Hemiaspis* 6. Of the latter, through *Ceratiocaris* and *Dictyocaris*, we have 16 species; and there are possibly one Amphipod (*Necrogammarus Salweyi*) and a Pœcilopod (*Neolimulus falcatus*, Woodw.). These 32 species of Merostomata and Pœcilopoda swell up the Crustacean fauna at the expense of the Trilobita, which number only 10 genera and 20 species, 2 genera only of the 10 (*Homalonotus* and *Phacops*) passing to or occurring in the Devonian rocks. The Ostracoda number 5 genera and only 13 species. The Crustacean remains termed Astacoderma by Dr. Harley, number 14 so-called species; all are in the

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Lower Ludlow. The whole Crustacean fauna, therefore, of the Ludlow rocks is 29 genera and 97 species. The Lower Ludlow contains 18 genera and 47 species, the Aymestry Limestone 9 genera and 12 species, and the Upper Ludlow 23 genera and 71 species. The Passage-beds into the Old Red Sandstone have yielded 9 genera and 15 species, 4 being Ostracoda, 1 Phyllopod (*Ceratiocaris decorus*), and 10 Merostomata (Eurypteridæ). No Trilobite occurs in the Passage-beds. This Passage-bed Crustacean fauna is what we should have anticipated; the Brachiopoda and Mollusca proper show the same indications of a change from a deeper to a shallow coast-line, and a fauna struggling to maintain life against new and adverse conditions. Shropshire through the Ludlow area possesses 18 genera and 46 species, Worcestershire 17 genera and 25 species, Herefordshire 14 genera and 26 species, Westmoreland 8 genera and 15 species. Scotland, chiefly through the Phyllopoda and Merostomata, has 12 genera and 22 species. Ireland only possesses 2 (*Calymene Blumenbachii* and *Phacops caudatus*). This deficiency of the Crustacea in Ireland, as indeed of all the classes except the Brachiopoda, bears out the fact of the smallness of the Ludlow fauna in Ireland. I am obliged to carefully detail the number of genera and species that range through and enter into the distribution of the Crustacean fauna on account of its peculiarities. 13 new genera made their appearance during the Ludlow period. 4 Ostracoda, *Cypridina*, *Entomis*, *Kirkbya*, and *Moorea*; 4 Merostomata (Eurypterida), *Himantopterus*, *Slimonia*, *Stylonurus*, and *Parka*; Xiphosura 1, *Neolimulus*; Phyllopoda 1, *Dictyocaris*; Amphipoda 1?, *Necrogammarus*; Crustacean remains, *Astacoderma* (14 species). 3 genera (*Stylonurus*, *Cypridina*, and *Parka*) occur in the Old Red Sandstone, but not in connected areas. 16 genera and 26 species are common to the Wenlock and whole of the Ludlow, thus reducing the true Ludlow Crustacean fauna to 71 species instead of 97.

Bryozoa.—*Heteropora crassa*, *Ceriopora sulcata*, and *Ptilodictya lanceolata* are the only 3 Ludlow Bryozoa. The first and last are Wenlock also. They occur in the Lower Ludlow and Aymestry Limestone of Worcestershire and Shropshire. *Ceriopora sulcata* occurs in the Ludlow of Ireland. No species occurs in the Upper Ludlow or Passage-beds, either in South or North Wales, Westmoreland, or Scotland. The nature of the Ludlow shales and mudstones doubtless was the cause why the Actinozoa, Hydrozoa, Echinodermata (Crinoidea &c.), and Bryozoa, all mostly dwellers in clear water, are so sparingly developed and distributed through the Ludlow rocks, the Aymestry Limestone being of little palæontological value owing to its lenticular disposition, mode of occurrence, and uncertain continuity.

Brachiopoda.—Although by no means a small fauna, the Ludlow Brachiopoda numbering only 48 species and 13 genera are less than half as numerous as those of the underlying Wenlock rocks. 41 of these 48 had lived in the Wenlock seas and passed to the Ludlow; therefore only 7 species are Ludlow proper; and only 3 species passed to the Devonian—*Atrypa reticularis*, *Strophomena* *rhomboidalis*, and *Lingula cornea*. The last named in the Ludlow country passes into the lowest beds of the Old Red Sandstone. The others named are "Devonian" of the North and South Devonshire areas, and not known in the Old Red proper. In the Passage-beds into the Old Red of Herefordshire, Shropshire, and Worcestershire some 5 or 6 species occur; they are *Chonetes striatellus* (*latus*), *Discina rugata*, *Lingula cornea*, *Lingula minima*, and *Strophomena rhomboidalis*. They are associated in places with a few Asiphonida of shallow-water habits, *Pterinæa*, *Modiolopsis*, *Orthonota*, &c. The Lower Ludlow has yielded 13 genera and 38 species, 33 of which are Wenlock. 12 genera and 25 species occur in the Aymestry Limestone, and 11 genera and 24 species in the Upper Ludlow; but no genus is peculiar to either the Aymestry or Upper Ludlow beds, the whole being represented in the Lower zone.

The only species in the Ludlow not Wenlock are *Lingula cornea*, *L. lata*, *Orthis canaliculata*, *O. lunata*, *Rhynchonella pentlandica*, and *Strophomena ornatella*. In other words, only these 6 species of Brachiopoda are really Ludlow forms. No species is known in North Wales, but 28 have been collected in South Wales. Herefordshire, Worcestershire, Shropshire, and Scotland have each yielded 11 genera, and respectively 23, 27, 30, and 15 species; Westmoreland has 8 genera and 14 species; Ireland 9 genera and 18 species.

Lamellibranchiata.—Both the Lower and Upper Ludlow possess a large Molluscan fauna; the Lower 14 genera and 34 species, and the Upper 15 genera and 56 species; the intermediate Aymestry Limestone only 4 genera and 7 species—*Pterinæa hians*, *P. retroflexa*, *P. Sowerbyi*, *Cardiola striata*, *Grammysia cingulata*, *Orthonota rotundata*, and *O. semisulcata*. The chief genera are *Pterinæa* with 12 species, *Anodontopsis* 7, *Orthonota* 16, *Modiolopsis* 5, *Ctenodonta* 4, *Cucullæa* 4, and *Grammysia* 4 species. The Passage-beds contain 9 genera and 19 species, yet *no single species occurs in* the Lower Old Red Sandstone; with the change of lithological characters all life seems to cease also, or no record is left. For the life-history of those rocks, equivalent in time to those of the Old Red Sandstone in the classical Silurian area, we have to consult the Devonian series of North and South Devon and Cornwall, where a fauna unsurpassed in perfection, if not in magnitude, in all the invertebrate classes exists—a group made famous in British geological history through the labours and researches of Sedgwick, Murchison, De La Beche, and Phillips. Westmoreland and Cumberland, through the researches of Sedgwick and M'Coy, Harkness and Nicholson, in the Kendal area, exhibit a large Ludlow Lamellibranchiate fauna; 12 genera and 37 species are known. Shropshire has 9 genera and 16 species, Worcestershire 8 genera and 17 species, Herefordshire 6 genera and 12 species, Scotland 6 genera and 13 species, and Ireland only 2 genera and 3 species. North Wales hitherto has yielded only 1 genus and 4 species; 13 genera and 21 species *ranged from the* Wenlock into the Ludlow, thus *altering the numerical* value of the Ludlow bivalves proper to 50 species, none of which passed the Passage-beds between the Upper Ludlow and Old Red Sandstone.

Extensive patches of Upper Silurian rocks on the eastern side of the Silurian area and border of the Old Red, such as Woolhope, Usk, the long strike of the Malverns on to May Hill, thence across the Severn at Purton Passage to Tortworth, indicate great physical changes in the borderland between the fossiliferous Upper Silurian and the unfossiliferous Old Red; and whatever change brought in the marine Devonian of North Devon, south of the Mendip axis and on the same strike, and all the South-Wales Old Red beneath the South-Wales coal-field to the Bristol Channel, certainly must account for the loss of all the Ludlow species; that the Devonian area was one of long and continuous depression south of the latitude of the Mendips there cannot be any doubt, and probably the mass of Old Red Sandstone occupying Caermarthenshire, Monmouthshire, Breconshire, Herefordshire, and Worcestershire was being at the same time slowly elevated.

Gasteropoda.—9 genera (six of which had appeared in the Wenlock) and 33 species, 11 of which were also Wenlock, range through the Ludlow rocks; the Lower Ludlow has yielded 8 genera and 15 species, the Aymestry Limestone 5 genera and 11 species, and the Upper Ludlow 9 genera and 21 species. 3 genera and 6 species occur in the Passage-beds into the Old Red Sandstone; they are *Holopella conica*, *H. gregaria*, *Holopæa obsoleta*, *Murchisonia torquata*, *Platyschisma helicites*, and *P. Williamsi*. They, however, cease here, none living into the red beds of the Old Red Sandstone. North Wales has yielded only 2 species, *Holopella gracilior* and *H. gregaria*; Scotland only 4 species, *Acroculia antiquata*, *Euomphalus funatus*, *Platyschisma simulans*, and *P. helicites*; Ireland has only registered 1 species, *Euomphalus alatus*; Herefordshire 7 genera and 11 species, Worcestershire 6 genera and 9 species, Shropshire 7 genera and 14 species, and Westmoreland 6 genera and 14 species. 6 genera and 13 of the 33 species come up from the Wenlock and range through the Ludlow rocks; they are *Acroculia haliotis*, *Cyclonema corallii*, *C. octavia*, *Euomphalus alatus*, *E. carinatus*, *E. funatus*, *E. rugosus*, *Holopella gracilior*, *H. obsoleta*, *Loxonema elegans*, *L. sinuosa*, *Murchisonia Lloydii*, and *M. articulata*. 9 species only are Lower Ludlow. All become extinct in the Tilestones and Passage-beds.

Pteropoda.—*Conularia subtilis* and *C. Sowerbyi*, with *Theca Forbesii*, are all the species (3) illustrating this pelagic group. The two last named are Upper Ludlow. Neither the Aymestry Limestone, Passage-beds, North Wales, or Worcestershire yield either species, nor do we know of any species in Ireland. *C. Sowerbyi* occurs in Scotland; all 3 species in Westmoreland and 2 (*Theca Forbesii* and *Conularia Sowerbyi*) in Shropshire. These last are also Wenlock species.

Heteropoda.—*Bellerophon* (6 species) and *Ecculiomphalus lævis* constitute the Ludlow stock of Heteropoda. *Ecculiomphalus lævis*, *Bellerophon expansus* and *B. dilatatus* occur both in the Lower and Upper Ludlow. *B. Murchisoni*, *B. obtectus*, and *B. trilobatus* are Upper Ludlow only; 4 species occur in the Passage-beds, *B. cari-*

natus, *B. expansus*, *B. Murchisoni*, and *B. trilobatus*; 6 species occur in the Upper Ludlow of Westmoreland; Shropshire and Worcestershire possess 3 of the same species. None are known in the Ludlow rocks of North Wales, Herefordshire, Scotland, or Ireland. *B. carinatus*, *B. trilobatus*, and *B. dilatatus* are also Wenlock species.

Cephalopoda.—No less than 24 species of *Orthoceratites*, 6 species of *Phragmoceras*, and 3 of *Lituites*, with other forms, make up the 6 genera and 37 species known in the Ludlow. *Ascoceras Barrandii* constitutes a new generic type. The Lower Ludlow has yielded 4 genera, *Lituites* (3 species), *Orthoceras* (15 species), *Phragmoceras* (6 species), and *Exosiphonites* (2 species).

The Aymestry Limestone has yielded 3 genera and 6 species—*Lituites giganteus*, *Orthoceras* 4 species, and *Phragmoceras ventricosum*. The Upper Ludlow 5 genera and 22 species—*Ascoceras Barrandii*, *Lituites giganteus*, *Orthoceras* 17 species, *Phragmoceras nautileum*, and *Tretoceras semipartitum*.

In the Passage-beds we have noted *Orthoceras bullatum* and *Tretoceras semipartitum*. 16 species of the genus *Orthoceras* occur in Westmoreland, mostly Upper Ludlow, and no other genus has yet occurred there. Shropshire possesses 4 genera and 22 species, embracing most of the species in the Upper and Lower Ludlow divisions; Herefordshire 5 genera and 21 species, *Ascoceras Barrandii*, *Lituites* 3 species, *Orthoceras* 11, *Phragmoceras* 3, *Exosiphonites* 2. Worcestershire has 10 species. *Orthoceras Maclareni* and *O. subgregarium* are the only Scotch forms known; and *O. subgregarium* is the only Irish species. 11 species come from the Wenlock rocks to the Lower Ludlow, but 16 Wenlock species range through the Ludlow group; *Ascoceras* is the only new genus; *and none ranged above into either Old Red Sandstone*, Devonian, or Carboniferous rocks.

Pisces.—No Vertebrata have yet been discovered in earlier rocks than the Lower Ludlow. *Scaphaspis* (*Pteraspis*) *ludensis*, Salt., is the first fish known, and the only species in the Lower Ludlow; none have yet been detected in the Aymestry Limestone, but every known Ludlow form occurs in the Upper Ludlow, and five of them in the Passage- or junction-beds, through which about 20 species of the Silurian fauna pass to the Lower Old Red Sandstone, 7 of which are Crustacea (Merostomata), 6 Fishes, and 2 Cephalopoda, &c.

The Crustacea common to the Ludlow and Old Red, and all belonging to one order, are *Eurypterus abbreviatus*, *E. acuminatus*, and *E. pygmæus*, *Pterygotus problematicus*, *Stylonurus Powriei*, *S. megalops*, and *Parka decipiens*. The fishes that connect the two formations, *but only in the Silurian area along the frontier* of the Old Red, are *Auchenaspis Salteri*, *Cephalaspis Murchisoni*, *C. ornatus*, *Pteraspis Banksii*, *Scaphaspis ludensis*, and *Eukeraspis pustuliferus*. All belong to the Ganoidei.

Devonian.

Plantæ.—We have no clue as to the region in which the Devonian Plants first appeared; and yet small as is the flora of the British Devonian as compared with that of North America it

Table XIV.—*Ludlow.*

From Wenlock.	Classes.	Genera.	Species.	Stratigraphical Distribution. Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage-beds.	Geographical Distribution. South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.	Pass to Devonian.
	Plantæ	5	5	...	...	4/4	3/3	...	...	...	3/3	2/2	2/2	1/1		
3/3	Protozoa	7	10	4/4	4/5	6/8	...	...	1/1	3/5	3/3	4/4	3/3			
1/2	Hydrozoa	1	8	1/8	...	...	...	...	...	...	1/8					
9/16	Actinozoa	12	17	12/17	7/8	3/7	...	6/9	1/1	5/6	9/13	9/12	5/7	1/1	4/6	
4/6	Echinodermata..............	12	21	11/19	3/3	6/7	1/1	1/1	2/2	6/7	6/9	2/3				
3/4	Annelida	9	17	6/7	3/4	7/15	3/3	6/9	3/4	4/6	3/5	5/7	4/4	3/3	...	1/1
13/18	Crustacea	29	97	18/47	9/12	23/71	9/15	12/21	3/3	8/15	18/46	17/25	14/26	12/22	2/2	3/8
2/2	Bryozoa.........................	3	3	3/3	2/2	...	...	...	...	...	2/2	2/2	1/1	...	1/1	
12/32	Brachiopoda...................	13	48	13/38	12/25	11/24	4/5	12/28	...	8/14	11/30	11/27	11/23	11/15	9/18	3/3
13/21	Lamellibranchiata	17	71	14/34	4/7	15/56	9/19	14/49	1/4	12/37	9/16	8/17	6/12	6/13	2/3	
6/9	Gasteropoda	9	33	8/15	5/11	9/21	3/6	8/17	1/2	6/14	7/14	6/9	7/11	3/4	1/1	
2/2	Pteropoda.....................	2	3	2/2	...	3/3	...	2/2	...	3/3	2/2	...	3/3	1/2		
2/3	Heteropoda	2	7	1/1	1/1	1/6	1/4	1/5	...	1/4	1/3	1/3				
3/11	Cephalopoda..................	6	37	4/25	3/6	5/22	2/3	3/14	1/2	1/16	4/22	3/10	5/21	1/2	1/1	1/2
	Pisces	10	14	1/1	...	9/14	4/6	5/8	...	...	8/11	...	1/1	...	...	4/6
73/129	....	137	392	98/222	53/84	102/258	39/66	70/163	13/19	57/127	88/187	70/121	62/114	39/63	20/32	12/20

shadowed forth the prolific flora of the Carboniferous epoch, which in the British Islands numbers 82 genera and 330 species; but the Devonian, which preceded it, has, up to the present time, yielded only 12 genera and 18 species. In America, however, about 95 genera and 160 species have been described through the researches of Dr. Dawson, Lesquereux, Vanuxem, Hall, Hartt, &c., especially the first-named author, who has devoted a long life to the elucidation of the Devonian and Carboniferous flora of the American region. 7 of the 12 British Devonian genera occur in America, viz. *Calamites*, *Lepidodendron*, *Psilophyton*, *Sagenaria*, *Sphenopteris*, *Stigmaria*, and *Trichomanites*; but our ill-preserved specimens scarcely admit of specific determination, in fact even their affinities are often difficult to make out; and the poverty of our flora is clearly seen from the few species (18) occurring to illustrate the 12 genera. On such slender evidence it is difficult to conceive from what area our Devonian and Old Red Sandstone flora was derived; whether migration took place from Central Europe or America. The facies appears to be American rather than European, this being the case with the Scotch and Irish floras, especially through *Psilophyton*, *Palæopteris*, and *Sagenaria*.

The Lower Devonian (Lower Old Red) has yielded 2 species, *Lepidodendron nothum*, Unger, and *Psilophyton Dechenianum*, Carr., with coniferous remains from Caithness and Wick in Scotland. The Middle Old Red contains *Caulopteris Peachii*, Salt. (=? *Psilophyton robustus*, Dawson), and the two mentioned as occurring in the Lower beds. The Upper Old Red species (12) approach closely to the Carboniferous. 7 genera and 12 species range through the Upper division—*Adiantites* 1 species, *Calamites* 1, *Filicites* 1, *Sagenaria* 5, *Sphenopteris* 2, *Trichomanites* 1, and *Knorria* 1. Thus only 18 species occur in the widely extended and thickly developed deposits of the Old Red of Scotland, the Silurian Old Red, and the rocks of the Irish area.

Protozoa.—*Scyphia turbinata*, *Sphærospongia tessellata*, and 5 species of *Stromatopora* all occur in the Middle Devonian; *Caunopora*, Phillips, *Sparsispongia*, D'Orb., and *Coscinopora* of Goldfuss are probably synonyms of *Stromatopora*. The Middle Devonian limestones of Torquay and Newton Abbot abound in the ever-varying forms of these incrusting Protozoa. The Devonian forms differ essentially from the Wenlock and Ludlow species, the type in those rocks being *S. striatella*, whereas the characteristic species in the Middle Devonian are *S. concentrica*, Goldf., and *S. placenta*, Lonsd., or the *Caunopora* of both Phillips and Lonsdale. No Protozoa occur either in the Lower or Upper Devonian, being strictly confined to the massive limestones of South and North Devon. *S. placenta*, *S. ramosa*, and *S. verticillata* are strictly British.

Actinozoa (*Actinoidea*, Dana; *Coralliaria*, M.-Edw.).—Perhaps during no period in the physical history of the British Islands have we had such a remarkable assemblage of Actinozoa as that which so essentially and specifically characterizes the Middle Devonian rocks of South and North Devon. Out of the 24 known genera and

52 species, *no single form passes to the Carboniferous, and none are common to the Silurian rocks in any area*; they stand alone, and are sufficient in themselves to maintain the integrity of the Devonian system. This is equally definite and distinct throughout the European or American areas, or wherever the Devonian rocks are developed. 15 genera illustrate the Zoantharia rugosa and 8 the Z. tabulata. The genus *Acervularia* numbers 7 species, *Alveolites* 4, *Cyathophyllum* 12, *Favosites* 5, *Smithia* 3, *Endophyllum* 2, and *Petraia* 2. The remaining 18 genera are only represented by 1 species each; 20 species are common to the rocks of North and South Devon, and 25 occur on the continent (Rhenish Prussia, Belgium, and France); none pass to the Carboniferous rocks in any region. The Lamellibranchiata, Gasteropoda, and Cephalopoda are all of equal stratigraphical value. The Middle Devonian group contains all the 24 genera and 48 of the 52 species. The Lower Devonian has hitherto only yielded 4 genera and 7 species; the latter are *Alveolites suborbicularis*, *Cyathophyllum helianthoides*, *Petraia celtica*, *P. gigas*, *P. pleuriradialis*, *P. bina*?, and *Pleurodictyum problematicum*; and the Upper Devonian also 4 genera and 7 species, viz. *Amplexus tortuosus*, *Cyathophyllum cæspitosum*, *C. ceratites*, *Fistulipora cribrosa*, *Michelinia antiqua*, *Petraia celtica*, and *P. pleuriradialis*. The researches of Dr. Nicholson upon the Devonian Corals of North America have thrown much light upon their history, habits, and mineralization; and it is to be hoped that his labours will be embodied in a volume upon the Rugose Corals, equal in interest and value to his late contribution on the Tabulata. Doubtless the Palæozoic Actinozoa of the British rocks now require critical revision, especially the Silurian and Carboniferous groups.

The Upper and Lower Devonian rocks are chiefly composed of slates, with here and there impure limestones. They therefore possess no coral fauna; whereas the highly developed masses of limestone around Torquay and Newton Abbot are simply Devonian coral reefs of great magnitude. In North Devon, between Ilfracombe and Linton, the limestones are lenticular, thin, and impure; yet more than one half of the entire known Devonian Actinozoa have occurred in them, and we have evidence of beds below at low-water level near Ilfracombe yielding even finer specimens than at Torquay. They have *to be searched for in North Devon and West Somerset*; patient working over that extensive area between Barnstaple and the Foreland with unbiassed views and a knowledge of the fauna which exists altogether independent either of the Silurian or Carboniferous, would readily convince those who have never examined the county that the rocks of North Devon between Baggy and the Foreland have nothing whatever to do with the Carboniferous system. The fossils alone, setting aside stratigraphical evidence and succession, determine the relation of this area to Belgium, the Rhine, and France; and their continuity under Somersetshire, Wiltshire, Berkshire, and Middlesex on to the continent is no longer matter of doubt or speculation, for the philosophical and far-seeing views and hypotheses of Mr. Godwin-Austen and Prof.

Prestwich have been fully realized, through the determination of the Devonian and Silurian rocks in Middlesex and Hertfordshire, immediately below the Cretaceous series.

Echinodermata.—7 genera of Crinoidea, 2 Asteroidea, and 1 Blastoid are all that are known of this class in the British Devonians. 80 genera have been described from the Devonian rocks of Europe and America. By comparison, therefore, the British fauna has scarcely any claim to recognition, and 5 of the 7 Crinoidea are also Carboniferous in Britain. It cannot be said, therefore, that the species in this division of the order are representative in Britain. The 10 genera and 24 British species are of necessity unequally distributed. *Actinocrinus tenuistriatus*, Phill., *Cyathocrinus megastylus*, Phill., and *C. pinnatus*, Goldf., are the only forms known in the Lower Devonian; 6 genera and 12 species occur in the Middle Devonian, viz. *Actinocrinus* 1 species, *Cupressocrinus* 2, *Cyathocrinus* 3, *Hexacrinus* 3, *Platycrinus* 2, and *Taxocrinus* 1 species.

The Asteroidea all belong to the upper division, and are mostly from the North-Devon beds, which with them have also yielded 7 Crinoidea. We have therefore 8 genera and 14 species in the Upper Devonian beds of North Devon—*Protaster* 2 species, *Palæaster* 2, *Helianthaster* 1, *Pentremites* 1, *Adelocrinus* 1, *Actinocrinus* 1, *Cyathocrinus* 5, and *Taxocrinus* 1 species. Of the whole fauna (24 species) 3 genera and 6 species pass to the Carboniferous; they are *Actinocrinus triacontadactylus*, *Cyathocrinus ellipticus*, *C. geometricus*, *C. pinnatus*, *C. variabilis*, and *Pentremites ovalis*. Three of these are European Devonian.

Annelida.—*Serpula advena*, Salt., occurs in the Upper Old Red Sandstone of Caldy Island, and *Tentaculites annulatus*?, Schloth., in the Middle Devonian of North Devon; the last named is abundant (in places) in the limestones near Ilfracombe.

Crustacea.—All the 4 orders, illustrated only by 20 genera and 37 species, are represented in the British Devonians; 45 genera and 290 species, however, have been described from Bohemia, Germany, Spain, Asia, Africa, America, &c. 20 of the foreign genera and 200 species are Trilobita; the remaining 90 are Merostomata, Phyllopoda, and Ostracoda. As in the case of the Echinodermata our Crustacean fauna is anything but representative, yet it has a characteristic facies that carries with it the conviction of distinctness. Only 6 genera of Trilobita are known, viz. *Bronteus* (*flabellifer*), *Cheirurus* (*articulatus*), *Harpes* (*macrocephalus*), *Homalonotus* (*elongatus*), *Phacops* (5 species including the subgenera *Trimerocephalus* and *Cryphæus*), and *Phillipsia* (*Brongniarti*); the doubtful genera have been relegated to their supposed places. 9 genera and 24 species of all the orders are Lower Devonian (6 genera are Trilobita), 5 genera and 6 species are Middle, and 7 genera and 9 species are Upper Devonian. *Eurypterus* (6 species), *Stylonurus* (6 species), and *Pterygotus* (4 species) are all, with one or two exceptions, Lower Old Red Sandstone types. None of these are known to occur in the typical Devonian area, being either Scotch or in the Silurian region. The singular genus *Præarcturus* (*P. gigas*, Woodw.) of the family Idoteidæ is from the Old Red of Herefordshire; this and *Proricaris M'Henrici* of Baily form the only 2 new British genera introduced into the Devonian fauna. *Phillipsia Brongniartii* is the only crustacean that occurs in common in the Devonian and Carboniferous rocks; it is the *Asaphus obsoletus* and *A. granuliferus*, Phill.; so that, small as the Devonian Crustacean fauna appears to be, it is nevertheless distinctive. A. Römer, Sandberger, Dalman, Brongniart, Richter, Münster, Beyrich, Steining, Roualt, &c. on the continent, with Salter, Phillips, Woodward, Jones, R. Etheridge, jun., and Baily in Britain, have all greatly enriched our knowledge of the Devonian Crustacea.

Bryozoa.—The Tubuliporidæ through *Ceriopora*, the Retioporidæ through *Fenestella*, *Hemitrypa*, *Polypora*, *Ptylopora*, and *Retepora*, and the Escharidæ through *Glauconome*, are represented through the Devonian rocks by the above 7 genera with 11 species; all the genera are equally Carboniferous, but only 4 species are common to both formations—*Ceriopora similis*, Phill., *Fenestella plebeia*, M'Coy, *Glauconome bipinnata*, Phill., and *Polypora laxa*, Sandb. The Lower Devonian possesses 2 species only, viz. *Fenestella antiqua*, also occurring in the Middle and Upper, and *Retepora repisteria*, which is also Middle Devonian. 6 of the 7 genera and 7 species are Middle Devonian—*Polypora*, through its representative species (*P. laxa*), being Upper and Carboniferous. 5 genera and 6 species are Upper Devonian; they are both South- and North-Devon forms—*Ceriopora* (*Millepora*) *gracilis*, Phill., *Fenestella antiqua*, Goldf., *F. prisca*, Goldf., *F. plebeia*, M'Coy, *Glauconome bipinnata*, Phill., and *Polypora laxa*. The known Devonian Bryozoan fauna (European, American, and British) consists of 26 genera and 115 species; of these we have only 7 genera and 11 species. These species range through North and South Devon and South Cornwall; they are rarely well preserved and always difficult to determine. Critical analyses of the species have been undertaken by Messrs. Shrubsole and Vines, who in time will revise the entire group.

Brachiopoda.—With the exception of the fishes of the Old Red Sandstone (125 species) this is the largest group in the British Devonian rocks. We should expect this when we know that no less than 61 genera and over 1100 foreign species have passed through the hands of European, American, and British zoologists and palæontologists, and all have been described; of these 1100 species only 116 are British; and of the 61 known genera we possess 26. *Calceola* (1), *Davidsonia* (3), *Cyrtina* (4), *Rensseleria* (11), *Camarophoria* (1), *Stringocephalus* (1), and *Uncites* (1) are the genera new to Britain, none of which made their appearance in our area until the Middle period of the Devonian deposits, the most marked and prolific of the three horizons. With the exception of *Cyrtina*, which exhibits 4 species, each of these genera is represented only by 1 species. Hall's genus *Rensseleria* yields 10 as the total value of the genus; but only 1 species occurs in Britain (*Rensseleria stringiceps*, Röm.); 8 of the rest are American, and 1 species is Coblentzian. I call attention to these 7 genera because they are essentially Devonian; the remaining 19 appeared in the Silurian rocks, and lived on through the Carboniferous.

The Lower Devonian yields 9 genera and 21 species—*Athyris* 1, *Atrypa* 3, *Chonetes* 3, *Leptæna* 1, *Orthis* 3, *Rhynchonella* 3, *Spirifera* 3, *Spiriferina* 1, *Streptorhynchus* 3. The Middle division contains 23 genera out of the 26, and 80 of the 116 species. The Upper contains 14 genera and 37 species; of these 10 genera and 16 species pass to the Carboniferous. It is essential to the history of the Devonian fauna that I name the genera—*Athyris* 2 species, *Chonetes* 1, *Discina* 1, *Lingula* 1, *Productus* 1, *Rhynchonella* 3, *Spirifera* 3, *Streptorhynchus* 1, *Strophomena* 1, *Terebratula* 2. The large genera are *Rhynchonella* 16 species, *Spirifera* 20, *Streptorhynchus* 6, *Orthis* 6, *Cyrtina* 4, *Productus* 4, and *Terebratula* 4. Regarding the great discrepancy or smallness of this peculiar fauna as compared with that of the continent and America, we must have regard to the smallness of the area now exposed in England as *compared with the original area occupied* by the Devonian sea, the accumulations of which are now covered by the Secondary and Tertiary rocks of the west and east of England, the Devonian floor or old surface being hidden east of the Quantocks, North Devon, and Torquay. We have proof of a rich Upper Devonian fauna in the rocks under London and Turnford, at the depth of 1000 feet, and below the Cretaceous series; between these two places and North Devon we can at present only surmise the plane they occupy.

The volume of the Palæontographical Society's publications by T. Davidson, Esq., F.R.S., &c., devoted to the British Devonian Brachiopoda, is worthy of the fame of its distinguished author; in it are described 116 species, the arguments for and against their genuineness being impartially and consummately reasoned out, figures of all the species and doubtful forms are given; and when we know the patience and skill required to adjust and discriminate so dismembered and small a group as the British Devonian Brachiopoda out of such a mass of material occurring in the European and American fauna (1100 species), we may well be thankful that there are men who have the required leisure and knowledge and who devote their lives to one subject. Associated with Davidson in the Devonian fauna, the names of Von Buch, Schlotheim, Schnur, Dalman, Sandberger, Hall, Billings, Dall, Conrad, Römer, Vanuxem, Barrande, De Verneuil, Roualt, Phillips, Sowerby, King, and M'Coy must be prominently noticed.

Lamellibranchiata.—The mass of the species of the class Conchifera occurring in the Upper Devonian, and especially abundant, are Asiphonida, through *Aviculopecten*, *Pterinæa*, and the Mytilidæ. 20 genera and 39 species are known, and 29 species illustrating 11 genera are in the Upper division; yet of the whole bivalve fauna only 4 genera and 5 species pass to the Carboniferous series in North Devon, viz. *Aviculopecten granosus*, Sow., *A. plicatus*, Sow., *Pterinæa damnoniensis*, Sow., *Cucullæa Griffithii*, Salt., and *Curtonotus unio*, Salt. The Lower Devonian is even poorer, only 3 genera and 4 species occurring; these are *Aviculopecten polytrichus*, Phill., *Pterinæa anisota*, Phill., *P. spinosa*, Phill., and *Ctenodonta Kratchæ*, Röm.; the last mentioned is the only bivalve species actually confined to the Lower Devonian. The Middle Devonian is represented by 13 genera exhibiting 23 species—*Aviculopecten* 2 species, *Pterinæa* 6, *Anodonta Jukesii*, *Cleidophorus ovatus*, *Corbula Hennahi*, *Cucullæa Hardingii*, *C. trapezium*, *Ctenodonta lineata*, *Leptodomus constrictus*, *Megalodon* 3, *Modiola scalaris*, *Pleurorhynchus* 2, *Pullastra antiqua*, and *Sanguinolaria elliptica*. *Megalodon*, *Pleurorhynchus*, *Corbula*, and *Cleidophorus* are generically and specifically essentially Middle Devonian. *Cucullæa* 6 species, *Curtonotus* 6, *Ctenodonta* 4, are the larger genera of the Upper Devonian beds of North Devon, south of the latitude of Baggy Point; but we have seen how few pass to the Carboniferous south of Barnstaple and Pilton, or along the strike of the two formations from Barnstaple to Braunton. The South-Petherwin and Land-lake beds in North Cornwall are Upper Devonian, and have yielded 65 species; they cannot be affiliated with the Carboniferous, the *Clymeniæ* and species of Orthoceratidæ forbidding it.

Any comparison of the insignificant British fauna with the splendid series of Devonian species in Europe and America is useless: no fewer than 90 genera and 900 species of Lamellibranchiata have been described; 260 are Monomyarian and 640 are Dimyarian species.

Gasteropoda.—13 British genera and 45 species constitute the entire list of the Odontophora. *No species occurs in the Lower Devonian.* The Middle, as in the case of all the other classes, contains the largest number of species (36) and 12 of the 13 genera—*Acroculia* 3 species, *Euomphalus* 5, *Loxonema* 5, *Macrocheilus* 6, *Murchisonia* 4, *Nerita* 1, *Pleurotomaria* 6, *Scoliostoma* 1, *Trochus* 1, *Turbo* 2, and *Vermetus* 2 species. The Upper Devonian species are 14, and occur mostly in the Pilton, Brushford, and Petherwin areas; they represent 7 genera—*Acroculia* 1, *Euomphalus* 1, *Loxonema* 4, *Macrocheilus* 1, *Murchisonia* 1, *Natica* 2, and *Pleurotomaria* 4. 5 species pass to the Carboniferous—*Acroculia vetusta*, *Loxonema rugiferum*, *L. tumidum*, *Murchisonia angulata*, and *M. spinosa*.

The South-Devon area has yielded 37 of the 45 Middle Devonian species, North Devon only 5, viz. *Euomphalus serpens*, *E. radiatus*, *Acroculia vetusta*, *Macrocheilus brevis*, and *Natica meridionalis*, and 11 Upper Devonian; the Petherwin beds in North Cornwall contain 7 Gasteropods, all Upper Devonian. Complete comparison of the two areas will be made at the end of the Devonian fauna.

Pteropoda.—No *Conularia* or *Theca* has appeared in the Devonian rocks of either South or North Devon. 30 species are known in the Devonian rocks of Germany and America.

Heteropoda.—The order Nucleobranchiata through the Atlantidæ is represented in all three divisions of the Devonian rocks by *Bellerophon* (5 species) and *Porcellia* (3). *Bellerophon bisulcatus* occurs in the Lower and Upper divisions; *B. striatus*, Lower and Middle; *B. hiulcus*, *B. subglobatus*, and *B. Urii* in the Upper; *B. hiulcus* and *B. Urii* appear also in the Carboniferous rocks. *B. subglobatus* is also a Coomhola species (Irish). *Porcellia Woodwardi*, Sow., and *P. striata*, Phill., occur in the Middle Devonian of South Devon; but *P. Symondsii* has hitherto only been found in the Upper division, or Pilton and Barnstaple beds south of Baggy. Thus these 2 genera and 8 species have a wide range, due to their pelagic habit; and regarding *B. Urii*, *B. hiulcus*, and *B. subglobatus* as Carboniferous, 3 occur in the Lower, 3 in the Middle, and 5 in the Upper Devonian. 5 genera and 77 species are Continental and American.

Cephalopoda.—*Clymenia*, *Cyrtoceras*, *Goniatites*, *Nautilus*, *Orthoceras*, and *Poterioceras* are the 6 British Devonian genera with 60 species. Other foreign genera and 500 species are known. We can hardly attempt comparison through such an extensive and widely disseminated group. (The genus *Goniatites* is illustrated by 168 species, *Clymenia* 50, and *Orthoceras* 130; but *Bactrites* with 9 species, *Cyrtoceras* 60, *Phragmoceras* 12, and *Trochoceras* 6 species, are not known in the British Devonians, besides many other smaller genera.) Strange as it may appear, only one species occurs in the Lower Devonian, *Cyrtoceras bdellalites*, Stutchb.; yet this genus is represented by 12 Middle and 2 Upper Devonian species. I am disposed to believe that we have not in Britain any Lower Devonian form at all, this single species from one locality being doubtful. The 11 other forms are all Middle Devonian.

Clymenia, the essential genus in the Devonian rocks of Britain (and elsewhere), numbers 11 species, and all occur in the Upper Devonian of Petherwin in North Cornwall. This genus is represented in Europe by 50 species, and, in the same stratigraphical position, in the Upper division of the Devonian series. America yields scarcely any *Clymeniæ*; and no *Clymenia* occurs in the Devonian rocks of North Devon, either Middle or Upper.

Goniatites.—In the Upper Devonian of Petherwin this genus is represented by *G. biferus*, *G. linearis*, *G. subsulcatus*, *G. striatus*, and *G. vinctus*; and 12 species occur in the Middle Devonian of Torquay; only 2 forms occur in the Upper beds of North Devon, *G. vinctus* and *G. spirorbis*; 4 of the Devonian species occur in the Carboniferous rocks, *G. carbonarius*, *G. excavatus*, *G. serpentinus*, and *G. subsulcatus*? As compared with the Carboniferous Goniatites, the Devonian group is of slight importance; in Britain alone we have 72 Carboniferous species, and 160 Devonian species have been described from European rocks, and only 6 or 8 from America.

Cyrtoceras.—With one exception the 13 species of this genus occur only in the Middle Devonian of Torquay. The single departure from this is *Cyrtoceras rusticum*, the only Upper Devonian form in the Petherwin beds; this species is probably the *C. arcuatum* of Steinmeyer. 60 species occur in the Devonian rocks of Central Europe; and, as in the two genera before noticed, few are American.

Orthoceras.—No species of *Orthoceras* has yet occurred in the Lower Devonian beds, either of North or South Devon. The Middle group at Torquay has yielded 8 species, and the Upper Devonian of North Devon 13; and 4 of these North-Devon species pass to the Carboniferous south of Pilton and Barnstaple, viz. *O. cinctum*, *O. lineolatum*, *O. striatum*, and *O. undulatum*. 130 species occur in the Devonian rocks of Rhenish Prussia and Central Europe, and less than 20 in America. Our Carboniferous rocks contain 47 species; but, as we have seen, only 4 species are common to the two formations.

Nautilus.—The European area, so rich in the 4 genera previously noticed, is unexpectedly poor in *Nautili*, not more than 11 species having been described therefrom, and only 4 or 5 from America. We possess only 2 species, *N. germanus* and *N. megasipho*; the former Middle Devonian, Torquay, the latter Upper Devonian, from Petherwin.

Poterioceras.—Only in the Upper beds at Petherwin is this genus represented, and by 1 species (*P. fusiformis*); it also passes to the Carboniferous rocks. The analysis of the Devonian Cephalopoda and their distribution show that the British species number 60, belonging to the 6 genera I have separately discussed. Only 1 is Lower Devonian; the Middle Devonian has yielded 4 genera and 33 species, and the Upper 5 genera and 33 species.

Looking, then, at our small Devonian Cephalopod fauna (6 genera and 60 species) as compared with that of Europe (20 genera and 500 species), which alone nearly equals all the species in the 14 classes in the British Devonian rocks (544), we readily see the value of this fauna in Europe, Belgium, the Eifel, the Harz, Saxony, the Fichtelgebirge, Russian Poland, Russia in Europe, and Spain.

In Belgium, France, the Eifel area, the Fichtelgebirge, and Saxony, the Devonian group, as with us, readily falls under the 3 divisions of Lower, Middle, and Upper, and in the main the grouping corresponds or may be correlated with our own. In Belgium (south of the Condros) the Psammite of Condros, the schists of Famenne, and the limestone of Frasne are the equivalents of our Upper Devonian as exhibited at Petherwin in North Cornwall, and the Baggy, Pilton, Brushford, and Marwood beds. The "Givet Limestone" at the summit of the Middle group is the equivalent of the *Stringocephalus*-beds of North Devon, but with us stratigraphically lower.

The *Calceola*-schists and the (*Spirifer*) "*Cultrijugatus*-Stufe" of Belgium are our *Calceola*-beds of Torquay and Newton in South Devon, and the typical Middle Devonian. The schists of Burnot, Ahrian, and the Coblentzian and Gadinian correspond with the Linton and Lower slates and grits of North Devon—our Lower Devonian (the lowest probably not seen). In the Eifel area, the beds of which, like the deposits of Belgium, correspond so closely with our own, the *Goniatite*-schists and (*Rhynchonella*) *Cuboides*-limestone are, like those of North Cornwall and Devon, the upper division; and, as in Belgium, the *Calceola*-schists and *Cultrijugatus*-Stufe are the equivalents of the South-Devon limestones or Middle Devonian: the Vichter schists, Ahrian (of Dumont), and the Coblentzian beds represent the mass of the lower shales, slates, and grits below the Hangman beds in North Devon. M. Gosselet*, in his succession of the Devonian rocks of North France and Belgium, divides the whole into 6 divisions or beds. The corresponding North-French beds to our Upper Devonian are probably the Psammites of Condros, the slates of Famenne, and the Boulonnais beds.

The Givet Limestone and Calceola-slates are our Middle Devonian, and the système Rhénan the Lower.

* Bull. Soc. Géol. de France, vol. xviii. p. 18.

M. Gosselet* again divides the Devonian of the Franco-Belgian region into Upper, Middle, and Lower, but with differences which have palæontological value.

His Upper Devonian contains the Psammites du Condros in 2 divisions; the Schistes de Famenne in 4 divisions.

The Middle Devonian one large group (calcaire de Givet) divided into 9 beds or bands.

In the Lower Devonian Gosselet places (1) the schistes à Calcéoles (in 3 divisions), (2) Poudingue de Burnot, (3) the Grauwacke à *Leptœna Murchisoni* (in 2 divisions), (4) the Couches de Gedinne and conglomerates and schists (in 3 divisions).

In the departments of the Loire Inférieur and Maine-et-Loire, according to M. Caillinaud, the Lower Devonian occupies large areas in the west of France; and in the same departments M. Bureau has determined the presence of the Upper Devonian.

In Rhenish Prussia, in the Eifel district, the Devonian strata were long studied by Ferd. Römer, of Breslau, and Dr. Emanuel Kayser. They determined the following horizons and successions†:—

The *Goniatite* schists *Cuboides* (*Rhynchonella*) limestone	Marly limestone, Upper Devonian.
Stringocephalus-schist *Calceola*-schist *Cultrijugatus*-Stufe (*Spirifer*)	Marl, Middle Devonian.
Vichter schist Ahrian schist (Dumont) Coblentzian	Sandy schists, Lower Devonian.

F. A. Römer, of Clausthal, has correlated the parallel horizons or deposits of the Harz and the Eifel. In the Eifel he gives 7 divisions, in the Harz 8; they are compared with Aix-la-Chapelle and Couvin.

In the 'Palæontographica' (for 1854), F. A. Römer divides the Devonian rocks of the Harz into 9 portions:—

1. Amay schists (jüngere Grauwacke).
2. *Cypridina*-schist.
3. *Goniatite*-schist.
4. Iberg limestone.
5. *Receptaculites*-schist.
6. *Stringocephalus*-limestone.
7. *Orthoceratite* or Wissenbach schist.
8. *Calceola*-schist.
9. *Spirifera*-sandstone (ältere or Rhenish Grauwacke).

Characteristic fossils are given with each, and the chief localities where the beds are exposed.

The Fichtelgebirge, through the researches of Prof. C. W. Gümbel‡, exhibit 4 divisions or groupings:—

1. *Cypridina*-schist	Upper Devonian (in 3 stages).
2. *Calamopora*-schist 3. *Tentaculite*-schist	Middle Devonian.
4. *Nereite*-schist	Lower Devonian.

* Annales des Mines, 6e sér. tom. xii. p. 595.

† Zeitschrift d. deutschen geol. Gesell. Jahrg. 1871, p. 375.

‡ 'Palæontographica,' Dunker and Meyer, xi. p. 109, "Ueber Clymenien in den Uebergangsbilden des Fichtelgebirges."

I have thus referred to some of the chief European localities and systems to show the importance and development of the continental Devonian rocks with their enormous fauna, as compared with the clearly determined but comparatively poor British series, our whole fauna only numbering 550 species at most. Unless some reference had been made to the American and European Devonians no force could have been given to the system; and its geographically disjointed state (even on the continent) tends to detract from the original unity of the whole, but at the same time to show that it was, and has been, one of the most extensive systems on the two continents, and even in the British Islands could we but uncover the extensive area between Belgium, the Boulonnais, and Devon and Cornwall, now deeply buried under the Secondary and Tertiary systems.

I cannot pass over the Devonian formation of North America and the Canadas, either physically or palæontologically, for we know, through the labours and researches of Hall, Bigsby, Newberry, Meek, Shumard, Winchell, Dawson, and others, how great and widely extended is the Devonian system in North America, and how persistent are the conditions and successions; the state of New York and the Canadas, with the Gaspé region in the east, have as yet exhibited the Devonian rocks in greatest development, all the three great horizons being present. The Hamilton and Upper Helderberg groups, with the Catskill, Chemung, and Portage groups above, occur in the States of Pennsylvania, Ohio, Illinois, Missouri, and Michigan in full development. In Iowa and Tennessee the Upper Devonian only is present. In New-York State the 11 recognized divisions make up a mass of limestones, sandstones, shales, flagstones, and conglomerates upwards of 8000 feet in thickness. In Pennsylvania the Devonians are 12,000 feet thick. The great Middle or Hamilton group is developed in 6 of the 8 States, the Lower or Helderberg in 4. Principal Dawson, in his 'Acadia,' has shown that the Devonians of the St.-John's area, New Brunswick, exhibit peculiar features different from those of the Western States before mentioned, but nevertheless are divisible into three stages or horizons*.

The above generalizations relative to the development and distribution of the European and American Devonians are given to show their great value and extent as compared with the really or comparatively poor fauna of the British Islands. That the whole formation or system once extended universally over the area thus roughly traced there cannot be any doubt, nor that probably during one general age one or other of its three divisions may have occurred homotaxially; but as a whole it occupied all that time or epoch extending from the close of the Upper Ludlow to the base of the Carboniferous. In North Devon its upper member passes insensibly and conformably into the Carboniferous, which is itself in an abnormal condition.

The Scotch and Irish beds of this age differ from all others, the

* 'Acadia,' 2nd ed. pp. 503–505.

Irish Coomhola beds, with *Anodonta* and *Palæopteris* or *Adiantites*, being undoubtedly of Upper Devonian or Upper Old Red Sandstone age. Mr. Kinahan would class the Old Red Sandstone of the Dingle and Cork area as Lower Carboniferous, and corresponding in the Limerick area to the Lower Carboniferous sandstones and shales. Kinahan further states that in no place in Ireland has the Old Red Sandstone a defined upper boundary, one group graduating into the other. Furthermore, he says, only in Munster and in the hills between Lough Erne and Pomeroy, in the counties of Fermanagh and Tyrone, is the Old Red Sandstone at the absolute base of the Carboniferous formation, as in all other places the rocks so called and described are on different geological horizons, ranging up to the base of the Coal-measures*.

As far back as 1863 Jukes and Salter stated that the yellow limestone of the South of Ireland is the upper part of the Old Red Sandstone, with the Coomhola grits between it and the Carboniferous slate with *Avicula damnoniensis* and *Cucullæa* &c.

Pisces.—50 genera and 125 species of fish range through the Old Red Sandstone. It can hardly be said that ichthyic life commenced prior to the commencement of the deposition of Old Red Sandstone or the Devonian age. The few genera and species that made their appearance in the British seas at the close of the Silurian period (8 genera and 12 species, 10 of which passed to the Old Red Sandstone) can only be traced into the very lowest beds of the Old Red in the Silurian area of Ludlow, Kington, and Ledbury, and scarcely passing beyond the passage group; we know them not higher in the system. In the North of Scotland and in the Orkneys, Caithness, and Cromarty area, the Lower Old Red Sandstone is known to have furnished 18 genera and about 60 species; no prior stratigraphical relation or origin is known. They occur in that region, like the strata or rocks which contain them, fully developed and in vast numbers. Unlike the Old Red Sandstone of the Silurian area the formation has there no fossiliferous base. The Silurian rocks are absent, the sandstones and conglomerates lying unconformably upon the metamorphic rocks. The only other organisms are Phyllopod and Eurypterid Crustacea, with remains of 10 or 11 genera of plants.

To no living geologist are we so much indebted for our intimate knowledge of the Old Red of Scotland as to Prof. A. Geikie. His paper in the 'Quarterly Journal of the Geological Society'†, on the Old Red Sandstone of the South of Scotland, and his last elaborate essay upon the Old Red Sandstone of Western Europe‡, are exhaustive so far as they have gone. Prof. Geikie shows that there is no middle Old Red Sandstone in either North or South Scotland,

* *Vide* Kinahan, 'Geology of Ireland,' pp. 50–94, for his views and much valuable information.

† "On the Old Red Sandstone of the South of Scotland." By A. Geikie, Esq., F.G.S. Quart. Journ. Geol. Soc. vol. xvi. pp. 312–323.

‡ "The Old Red Sandstone of Western Europe." By A. Geikie, LL.D., F.R.S. Trans. Roy. Soc. Edinburgh, vol. xxviii. 1878.

but that it consists only of two great divisions—a lower, passing down conformably into the Upper Silurian shales, and an upper, graduating upward into the Lower Carboniferous sandstones, with a complete discordance between the two series.

Prof. Geikie in his memoir traces the series of changes in the physical geography of Western Europe which took place between the close of the Upper Silurian and the commencement of the Carboniferous period. Viewed in a large sense the Old Red Sandstone of Great Britain groups itself stratigraphically into two divisions, physically and palæontologically distinct, a lower and an upper.

Prof. Geikie regards the Old Red as a great lacustrine accumulation, and treats of the separate basins of deposit as lakes, to which he has assigned different names:—

1. *Lake Orcadie.*—"Embracing all the Old Red Sandstone to the north of the Grampian range, including all the Orkney Islands."
2. *Lake Caledonia or the Mid-Scottish Basin.*—"Occupying the central valley of Scotland between the range of the Highland mountains on the north and that of the Silurian pastoral uplands of the southern counties. This basin was probably prolonged across the Firth of Clyde into the north of Ireland."
3. *Lake Cheviot.*—"A portion of the south-east of Scotland and the north of England, extending from near St. Abb's Head south-west along the base of the Silurian hills to the head of Liddesdale, and including the area of the Cheviot Hills."
4. *The Welsh Lake.*—"The Old Red Sandstone region of Wales, bounded on the north and west by the Cambrian and Silurian rising grounds, but its eastern and southern extension obscured by later formations."
5. *Lake of Lorne.*—"A district in the North of Argyllshire extending from the south-east of Mall to Loch Awe, and perhaps northward up the line of the great Glen."

At p. 374 of his memoir Mr. Geikie gives the order of succession among the strata, the thickness, and typical localities of the Old Red of Caithness, which he makes 16,200 feet thick, and then treats of all the subdivisions separately. Pp. 406–414 treat of the Orkney Islands palæontologically and physically; and pp. 414–421 of the Shetland Islands in the same manner. The description of the Basin of the northern Firths occupies 26 pages.

I commend this great addition and acquisition to the history of the Old Red Sandstone of Scotland to every student of geology.

Professor Hull has lately ably discussed the vexed question of the geological relations of the rocks of the south of Ireland to those of North Devon and other British and continental districts*.

Mr. Hull had previously discussed, in his paper upon the Dingle beds and Glengariff grits and slates†, the relations of the Upper

* Quart. Journ. Geol. Soc. vol. xxxvi. pp. 255–276 (1880).

† Quart. Journ. Geol. Soc. vol. xxxv. pp. 699–723.

Silurian series of the south-west of Ireland to those of the Silurian region of England, and also the relation of the Old Red Sandstone to the Dingle beds, and shown that, as in the north of Scotland, all through the south and centre of Ireland the Old Red is everywhere unconformable to the rocks on which it reposes, while it passes up conformably into the Carboniferous series.

Prof. Geikie has suggested that the Dingle beds or Glengariff grits may represent the Old Red Sandstone of Scotland (*loc. cit.*). Should this be the case they would be the marine representatives of lacustrine deposits. Both, according to Mr. Hull, are unconformably overlain by Upper Old Red conglomerate and sandstone.

Mr. Ralph Tate held the view that the Dingle beds are the equivalents of the Tilestones or Passage-beds of England and Wales*, or the lowest Old Red. Prof. Hull endeavours to show that between the Glengariff beds and the succeeding formation, be it what it may, either Old Red Sandstone or Carboniferous, there is a great blank, or, in other words, "unrepresented time." This long period Mr. Hull believes was filled up in the south and south-west of England and in Belgium by the extensive series known as the "Middle" and "Lower Devonian beds," lying between the "Foreland grits" on the one hand and the "Pickwell-Down Sandstone" on the other. Prof. Hull also believes that "while a deep sea, in which were deposited the Middle and Lower Devonian beds, overspread the south of England and adjoining continental areas, land conditions prevailed in the south of Ireland during the same period."

The analogy between the Old Red Sandstone of the south of Ireland and its supposed representatives in North Devon, Belgium, and Scotland receives critical analysis from Mr. Hull. That author endeavours to demonstrate that the Middle and Lower Devonian rocks of North Devon are totally unrepresented in the Irish area, no correlation being possible above the Foreland beds. I believe no one who has ever examined the area south of the Pickwell-Down Sandstone can doubt that the Baggy, Marwood, Croyde, Barnstaple, and Pilton beds are upon the same general horizon as the Carboniferous slate and Coomhola grits of Ireland, and that the Pickwell-Down Sandstones represent the Upper Old Red Sandstone of the south of Ireland. Both on physical and palæontological grounds these two groups seem to agree. Although the freshwater shell *Anodonta Jukesii* has not occurred in the Baggy or Pilton series in North Devon, its plant associate, *Adiantites* (*Palæopteris*) *hibernicus*, has been found in the Baggy beds, or immediately above the Pickwell-Down Sandstone (Upper Old Red). I do not despair of finding the Irish shell in North Devon, especially after its occurrence in Northumberland in the lowest Carboniferous rocks of that area. We may well believe that the "lacustrine" conditions of the south of Ireland gave place to marine conditions over the Devonian area during the same time.

Mr. Hull proposes the following tabulated form as representative for two areas, viz. the south of Ireland and North Devon :—

* Weale's series. Geology. Portlock and Tate, p. 72.

	South of Ireland.	North Devon.
Lower Carboniferous beds.	Carboniferous Limestone. Carboniferous Slate. Coomhola Grit and Slate (passage-beds.	Carboniferous Limestone. Barnstaple beds. Pilton beds. Baggy and Marwood beds (*Cucullæa*-zone).
Old Red Sandstone or Upper Devonian.	Kiltorcan beds. Old Red Sandstone and Conglomerate.	Upcot beds? Pickwell-Down Sandstone.

Prof. Hull then enters minutely into the question of the equivalency and relationship of the North-Devon, Lower and Middle Devonian series to beds, if any, in the South-Irish area. The Irish Upper Old Red Conglomerate does not appear to have had, in that area, any immediate predecessor; and Mr. Hull suggests and contends that the unconformity between the Glengariff beds and the Old Red or Carboniferous beds proves that certain strata are absent or were never deposited over the South-Irish area. If Mr. Hull's correlation be correct, it may possibly follow that the Middle and Lower Devonian of North Devon may occupy the place of the missing strata in the south of Ireland. Furthermore, Mr. Hull regards the Foreland grits and slates (the base of the North-Devon beds) as representing in part the Glengariff beds, which he believes to be of Upper Silurian age. The Foreland grits and sandstones, the recognized base of the Devonian rocks in Devonshire, Mr. Hull would correlate with the uppermost Silurian or Passage-group of Sir R. Murchison; and he also infers that the great gap which appears to exist in Ireland between the Glengariff beds and the succeeding Old Red Sandstone and Carboniferous series was filled up in North Devon by the Mortehoe slates, the Ilfracombe series, and the Lynton beds, or all the strata that exist between the base of the Pickwell-Down Sandstones and the top of the Foreland grits. Mr. Hull's views as regards the representative beds in the south of Ireland, North Devon, and Belgium are carefully tabulated on p. 266 of the 'Quarterly Journal of the Geological Society,' vol. xxxvi., 1880, the relations of each group being given. The Belgian and Boulonnais sections are also referred to and tabulated. Scotland, through Geikie's latest memoir (*loc. cit.*), is compared with both areas, Devon and North and South Ireland. On page 273 is also given a table of representative formations for Ireland, North Devon, South Wales, Scotland, and Belgium. These two contributions, by Professors Geikie and Hull, to the history of the Old Red and Devonian rocks of Scotland, Ireland in part, and North Devon have materially added to our knowledge of their physical history and condition.

The distribution of the 49 or 50 genera and 125 species of fish through all the known deposits of Old Red in the British Islands seems to result in there being no middle fish-bearing group, either in England, Scotland, or Ireland. Only 2 genera and 2 species are regarded as Middle Old Red, *Eucephalaspis* (*Cephalaspis*) *Agassizi*, Lank., and *Holoptychius Murchisoni*, Ag.; but it would hardly appear that these two species are rightly placed stratigraphically.

On palæontological grounds this fully confirms the most recent researches relative to the absence of the Middle Old Red Sandstone in Scotland and Ireland, and probably in the Welsh area also.

8 genera and 12 species of Elasmobranchii (Placoidei) range chiefly through the Lower Old Red—many with only 1 representative, viz. *Byssacanthus*, *Conchodus*, *Cosmacanthus*, *Ctenacanthus*, *Ctenoptychius*, and *Parexus*; also *Onchus* with 4 and *Ptychacanthus* with 2 species. The remaining 114 species represent 9 families and 41 genera, all Ganoidei:—

	Genera.	Species.
1. Cœlacanthini	2	2
2. Placodermi	3	10
3. Cephalaspidæ	15	40
4. Cheirolepini	1	4
5. Glyptodipterini	8	23
6. Saurodipterini	3	9
7. Ctenodipterini	2	2
8. Phaneropleurini	1	1
9. Acanthodæ	6	23
	41	114

The Lower Old Red is represented by 36 genera and 85 species, and the Upper by 15 genera and 25 species; and I know *of no species* that is common to the Old Red Sandstone proper and the Carboniferous group above.

Those genera that seem to specially characterize the Upper Old Red Sandstone, chiefly Scotch, are *Actinolepis*, *Asterolepis*, *Bothriolepis*, *Cosmacanthus*, *Dendrodus*, *Glyptolæmus*, *Glyptopomus*, *Holoptychius* (some species), *Homothorax*, *Lamnodus*, *Pamphractus*, *Phaneropleurus*, and *Phyllolepis**. The 2 genera (?) and 2 species (?) in the so-called Middle Old Red tend also to show, through physical research, that no such grouping exists.

56 genera and 150 species, other than British, have been recognized in Europe and America, but are allied through about 40 genera, or that number is common to all three areas, America, the British Islands, and Europe.

Of the entire British Devonian and Old Red fauna (544 species) we have seen that 32 genera and 51 species pass to the Carboniferous. I give the number of species in the classes that connect the two epochs:—

* Dr. Traquair is now engaged in carefully revising and describing the Ganoid fishes of the Old Red Sandstone. They could not be in better hands; few men are so competent to undertake so large a task. Many names are only provisional.

	Genera.	Species.
Plantæ	2	2
Protozoa	none pass.	
Actinozoa	1	1 ?
Echinodermata	3	6
Annelida	none.	
Crustacea	1	1
Bryozoa	4	4
Brachiopoda	10	16
Lamellibranchiata	4	5
Gasteropoda	3	5
Pteropoda	none.	
Heteropoda	1	2
Cephalopoda	3	9
Pisces	none.	
	32	51

It will be seen that, out of the 51 species, the two large connecting groups are the Brachiopoda and the Cephalopoda.

Professor Hull, in May 1880, communicated a paper to the Royal Dublin Society "On the Relations of the Carboniferous, Devonian, and Upper Silurian Rocks of the South of Ireland and those of North Devon"*; and although resembling his previous paper "On the Geological Relation of the Rocks of the South of Ireland to those of North Devon &c.," it treats of the subject-matter in a different light. Prof. Hull enters more into the palæophysical geography of the south of Ireland and North Devon, as indicated by the relation of the formations and areas respectively. In the south-west of Ireland, north and south of Dingle Bay, the rock-groups which rise into high elevations belong to the Dingle beds or Glengariff grits and slates of Professor Jukes. The lowest beds of the Dingle promontory do not reach the surface amidst the mountain-ranges to the south of Dingle Bay.

The Glengariff beds may measure about 10,000 feet in thickness. There is a total absence of the Old Red Sandstone at the base of the Carboniferous beds†. Contortions in the Glengariff beds are of earlier date than the deposition of the Old Red Sandstone or Carboniferous beds; this therefore implies that between the Glengariff beds and the Old Red Sandstone there is a vast amount of wanting strata, indicative also of unrepresented time—in other words, a wide gap and prolonged interval of time actually separates the two formations. It is the representation or filling up of this gap that Prof. Hull endeavours to show through the uninterrupted sequence in the Middle and Lower Devonian beds of North Devon, or through the whole series from the lowest Devonian up to the base of the Carboniferous

* Proc. Royal Dublin Soc. vol. i. new series, 1880, pp. 135–150.

† Hull, "On the Geological Age of the Rocks forming the Southern Highlands of Ireland," Quart. Journ. Geol. Soc. vol. xxxv. p. 699 *et seq.* (1879).

formation in that area. In no other district do we find evidence to account for such loss, or beds that can be correlated with those of the south of Ireland. Mr. Hull tabulates the succession of the Carboniferous and Devonian rocks of North Devon and the south of Ireland, and endeavours to show their relation and probable contemporaneity as follows* :—

	North Devon.	South of Ireland.
Lower Carboniferous series.	Earthy limestones, with *Posidonomya* (Venn Quarry).	Carboniferous limestone.
	Barnstaple slates.	Lower Carboniferous slate.
	Pilton beds.	Coomhola grits and slates (with *Cucullæa* &c.).
	Marwood beds (*Cucullæa*-zone).	
Upper Devonian.	Upcot flagstones.	Kiltorcan beds (with *Anodonta Jukesii*).
	Pickwell-Down sandstones.	Old Red Sandstone and conglomerate.
Middle Devonian.	Mortehoe slates.	Strata absent over the area in the south of Ireland.
	Ilfracombe limestone group.	
	Hangman grits (Martinhoe beds).	
Lower Devonian and Upper Silurian.	Lynton shales and limestones.	
	Foreland grits (base invisible).	Glengariff beds, passing down into the Upper Silurian beds.

The above table is probably the true reading of the areas under notice. This table is followed by a concise description of the North-Devon formations and their fossils, in descending order, from the Carboniferous series south of Barnstaple to the Foreland grits. It is worthy of attentive study; and Mr. Hull has marked with an asterisk the identification by Mr. Baily of those species also occurring in the Carboniferous and Coomhola beds of the south of Ireland, thus showing still further, on palæontological grounds, the relationship between the now separated, but probably once united, areas.

Mr. Hull's views "that the missing chapter between the Silurian and the Carboniferous, in the palæontological history of Ireland, is supplied by the rocks of Devonshire with their marine organisms" is probably near the truth; and the proportions assumed in the geological series by the Devonian rocks "offers a solution to one of the problems of Irish geology."

Professor Hull enters into geographical considerations of a minute character, to which I must refer, and which bear significantly upon the relative changes of sea and land from the Silurian to the close of the Carboniferous period. The successive phases of the physical conditions are given through four diagrams of the British Islands on plate v., which show the relations of land and sea, or elevation and depression.

He believes that there is only one true Old Red Sandstone in North Devon, which is represented by the Pickwell-Down Sandstone, and that the Upper Old Red of Scotland and Ireland is not the equivalent of the Devonshire marine Devonian strata, which are newer and

* Hull, *loc. cit.* p. 144.

higher. If Prof. Geikie is right in saying that the Scotch Old Red Sandstone represents the Irish Glengariff beds, then Prof. Hull may be right in concluding that the Scotch beds are the lacustrine equivalents in time of the marine uppermost Silurian strata, the Upper Scotch Old Red being the equivalent of the same in Ireland.

Table XV.—*Devonian.*

From Ludlow.	Classes.	Genera.	Species.	Lower Devonian.	Middle Devonian.	Upper Devonian.	Pass to Carboniferous.
	Plantæ	12	18	2/2	3/5	7/12	2/2
	Protozoa	3	7	...	3/7		
	Hydrozoa.						
	Actinozoa	24	52	4/7	24/48	4/7	1/1
	Echinodermata	10	24	2/3	6/12	8/14	3/6
1/1	Annelida	2	2	...	1/1	1/1	
3/8	Crustacea	20	37	9/24	5/6	7/9	1/1
	Polyzoa	7	11	2/2	6/7	5/6	4/4
3/3	Brachiopoda	26	116	9/21	23/80	14/37	10/16
	Lamellibranchiata	20	39	3/4	13/23	11/29	4/5
	Gasteropoda	13	45	...	11/36	7/14	3/5
	Pteropoda.						
	Heteropoda	2	8	2/3	2/3	2/5	1/2
1/2	Cephalopoda	6	60	1/1	4/33	5/33	3/9
4/6	Pisces	50	125	36/85	2/2	15/25	
12/20	......	195	544	70/152	103/263	86/192	32/51

Contents: 195 genera, 544 species.
Pass to Carboniferous: 32 genera, 51 species.

Carboniferous System.

We must go back beyond the present decade for new matter bearing upon the history and distribution of the British Carboniferous species—not that any significant change has taken place in the nomenclature or division of the groups, but speculative and philosophical views have been propounded by many authors upon the distribution and redistribution of the Carboniferous land-surfaces and their relation to still older areas. No one has contributed more than Professor Hull to the elucidation of the Carboniferous strata in England, Scotland, and Ireland. This is notably the case with his paper on iso-diametric lines representing the distribution of sedimentary strata as distinguished from calcareous strata with reference to the Carboniferous rocks of Britain *, also his paper upon the evidence of a ridge of Lower Carboniferous rocks crossing the plain of Cheshire beneath the Trias &c.† Another and equally important communication was brought by him before the Society "On the Thickness of the Carboniferous Rocks of the Pendle Range of Hills in Lancashire, illustrating the author's views regarding the South-easterly Attenuation of the Carboniferous Sedimentary Strata of the North of England"‡. This was followed by another paper entitled, "Observations on the Relative Ages of the leading Physical Features and Lines of Elevation of the Carboniferous District of Lancashire and Yorkshire" §. Prof. Hull again in 1876 still further enriched the literature of the Carboniferous system through a valuable and exhaustive paper "On the Upper Limits of the essentially Marine Beds of the Carboniferous Group of the British Isles and adjoining Continental Districts, with Suggestions for a fresh Classification of the Carboniferous Series" ||. I consider these contributions of Mr. Hull of the highest importance, as bearing upon theoretical geology, and tending to excite us to closer research and broader views as to the physical geography and distribution of life during the Carboniferous period—certainly one of the most prolific during Palæozoic times, governed by the distribution of land and water or their relations one to the other, under marine, estuarine, and freshwater conditions.

The nature of sediments, whether physical (such as inorganic sandstones, clays, and shales) or organic (as calcareous marine or freshwater limestones and their relation to life during deposition), has hardly received the attention it demands. Little has been written relative to these since Dr. Bigsby, in his memorable papers in 1858–59, entered into the history and nature of the sediments laid down over the sea-bottoms, and the immediate relations of animal life to the strata which the fossil remains now occupy. He made comparisons of the State of New York and Wales for obvious reasons. Bigsby showed, through his elaborate researches, that, owing to a determinate law (with few exceptions), the accumulated "sediments graduate into each other, clearly seen in Wales, Scandinavia, Russia, and America." The change in sedimentation usually takes place slowly and tranquilly, and the majority of life in the uppermost or terminated section perishes, thus showing that destruction or change can take place without any marked disturbing force. This is perhaps more manifest in the accumulation of the Carboniferous strata throughout Britain than probably in any other formation. The marked difference, yet, on the whole, agreement between the Scotch and border formations, or the Calciferous Sandstone, north of

* "On Iso-diametric Lines as means of representing the Distribution of Sedimentary Clay and Sandy Strata as distinguished from Calcareous Strata, with Special Reference to the Carboniferous Rocks of Britain." Quart. Journ. Geol. Soc. vol. xviii. pp. 127–146 (1862).

† *Loc. cit.* vol. xxix. p. 171. ‡ *Loc. cit.* vol. xxiv. p. 319.

§ *Loc. cit.* vol. xxiv. p. 223 (1868).

|| *Loc. cit.* vol. xxxii. pp. 613–651 (1876).

the Cheviots to the latitude of Burnt Island, and those same strata south of the Tweed to the latitude of Harbottle and on towards Rothbury &c., would seem to be due to comparatively small changes of conditions; and from the mapping by the Survey, Prof. Hull's suggestion as to the origin of and difference between the calcareous and true sedimentary or argillo-arenaceous strata, especially as exhibited in the Upper Silurian, Devonian, and Carboniferous formations, appear to be confirmed. Mr. Hull regards the true calcareous strata as different in origin and distribution from the other stratified rocks with which they are associated,—not, indeed, properly coming under the term sedimentary, this term being restricted to "gravels, sandstones, shales, and clays," the presence of both classes of rock in the same geological group being no argument in favour of their similarity. Whenever interstratifications occur the limestones may be regarded as occupying neutral ground between the respective areas of dispersion of the sedimentary series. Could it be possible to trace the sources of the "sedimentary" strata of any formation on the one hand and of the limestones on the other, they would be found expanding in opposite directions, this arising from the difference in the origin of the two classes of stratified rocks, the calcareous being essentially organic and the sedimentary essentially mechanical. We may, I believe, regard the predominance of "sedimentary strata" as highly unfavourable to the development of calcareous deposits in the same group of rocks, from the fact of interference with the development of life.

Looking at the physical geology of Britain prior to the deposition and distribution of the Carboniferous strata it is probable that "a barrier of land existed, stretching from Wales eastwards, touching the southern ends of the South-Staffordshire and Warwickshire coal-fields, and including the Cambrian rocks of Charnwood Forest." This barrier Prof. Hull believes was possibly an extension of the Scandinavian promontory, stretching across the Irish Sea to embrace the Cambro-Silurian districts of Wicklow and Carlow, and dividing the Carboniferous rocks of South Wales, Somersetshire, and Dean Forest from the coal-tracts of Central and Northern England and Scotland, the strata on each side belonging to two distinct systems of distribution; and their origin is therefore "due to two different sets of oceanic currents" (Hull).

The correlation of the Carboniferous rocks of Britain and Ireland is even now a matter of difficulty and of difference amongst those best able to decide. Even the continuous series between England and Scotland from the Calciferous Sandstones of Fife, south of the Cheviot, to the Yoredale series of Durham are most difficult to correlate—much that has been called Carboniferous Limestone being calciferous in one area and even Yoredale in the other. The literature of the whole question is scanty and unsatisfactory in the extreme; and in the construction of my Tables these difficulties have met me everywhere. The wide difference that exists in the mode of derivation and accumulation of the materials composing the sedimentary series of the northern and southern groups, as well as their zoological differences, are matter for much research. Materials have not long been obtained whereby we may institute comparisons between the different members even of the British group of Carboniferous rocks, setting aside our intimate connexion on the one hand with the European, and on the other with that of the American continent, especially New Brunswick and Nova Scotia, whose relation to Scotland through the Coal-measures can hardly be doubted. Those beds which overlie the Carboniferous Limestone in the south of Ireland have hardly yet had assigned to them their true place by correlation with those of England; neither has it been satisfactorily settled what is the precise stratigraphical commencement of the Lower Carboniferous series of the North-Devon area, or where the line should be drawn between the Upper Devonian and Lower Carboniferous. Both horizons are fossiliferous, and it is only in the south of Ireland that we have similar conditions, or where a comparison can be instituted between the two. Again, as regards the Coal-measure "shales and flags" immediately overlying the Carboniferous Limestones of the south of Ireland, there can be no doubt that they represent the Millstone Grit of the English Coal-fields. This was the opinion of the late Professor Jukes, who, in the explanatory memoir to sheet No. 137 of the Irish Geological Survey maps, says, "Doubtless the whole of the Coal-measure series of Central Ireland is contemporaneous with the lower part only of that of Central England, including the Millstone Grit in that lower part." Prof. Hull also doubts not that through the identification of the Gannister beds in the Leinster Coal-field, which, in the north of England, overlie the Millstone Grit, that contemporaneity, to a large extent, occurs between the English and Irish Carboniferous beds, and this especially on physical grounds.

Through the close research of the Irish Survey in the Leinster and Munster Coal-fields they are now enabled to trace out and distinguish four divisions:—1, the Yoredale beds; 2, the Millstone Grit; 3, the Gannister beds; and 4, the Middle Coal-measures as determined in England. Hitherto they have simply been classed under the general term "Coal-measures."

Professor Hull endeavours to show to what extent the British Carboniferous rocks have their representatives in Ireland; and he also proposes to establish a "Middle Carboniferous series," which shall include all the strata lying between the Carboniferous Limestone and the Middle Coal-measures, including the Yoredale beds, Millstone Grit, and Gannister beds. Mr. Hull is careful to impress upon us the fact that the Yoredale beds of Ireland are more intimately associated with the Millstone Grit and Gannister beds than with the Carboniferous Limestone; hence his reason for proposing the new classification. In England the Yoredale beds are most closely allied to the Carboniferous Limestone, upon which they conformably rest.

Mr. Hull minutely describes the main features of the Southern and Northern Irish Coal-districts and their subordinate Coal-fields.

In the southern coal-fields of Carlow, Queen's County, Kilkenny, &c. the succession of the strata above the Carboniferous Limestone is remarkably uniform and constant; any one may be taken as the type of the whole, having reference to an English standard for comparison *.

The Northern Coal-district in Ireland includes the Leitrim and Tyrone Coal-fields, which are representative of the southern in all their successive beds and stages. Isolated geologically occurs the Ballycastle Coal-field of Co. Antrim, the Irish representative of the Clyde Coal-basin, of Lower Carboniferous age, a conclusion established and confirmed through its fauna. The Carboniferous Limestone here is only a few feet in thickness, its place being taken by sedimentary or mechanical deposits. This is paralleled in North Britain; but the same beds thicken to the south-west in Derbyshire and attain a thickness of 5000 feet of solid limestone.

The English and Scotch Carboniferous districts and their respective coal-fields receive from Prof. Hull terse but careful analysis in his paper, each coal-field being divided into recognized stages varying from A–G, or from the Calciferous Sandstone series of the Scottish beds (A) to the Upper Coal-measures of any coal-field (G).

I deem it important for my analysis of the Carboniferous system to state concisely the subdivisions or stages into which they are divided. I adopt the classification clearly given by Professor Hull, which is mainly that of the English, Scotch, and Irish surveys. I omit the physical characters of the beds, reference to his paper being better †.

The British Carboniferous Series in descending order, with localities.

	Names of Formations.	Localities.
Essentially Freshwater and Estuarine Beds.	Stage G. *Upper Coal-measures.* Thin coal-seams and limestones. Fossils (freshwater or marine): Fish; Crustacea, *Cythere inflata*; Annelida, *Spirorbis carbonarius.*	Manchester, Stoke-on-Trent, Newcastle-under-Lyne, S. part of Dudley Coal-field; banks of the Dee near Ruabon; Hamilton and Ayrshire, Scotland.
	Stage F. *Middle Coal-measures.* Thick coals. Fossils (freshwater or estuarine): Fish; Mollusca, *Anthracosia, Anthracomya*; Crustacea, *Beyrichia, Estheria*; Annelida, *Spirorbis.* Marine species rare.	Central portions of all the coal-fields of England and Wales; Upper Coal-measures of Scotland.

* Prof. Hull describes the Castlecomer and Killenaule Coal-fields. *Vide* explanations of Sheets 136 and 137 of maps of the Geological Survey of Ireland; also the Slieveardagh Coal-field, Co. Tipperary.

† Quart. Journ. Geol. Soc. vol. xxxiii. pp. 613–616.

British Carboniferous Series &c. (continued).

	Names of Formations.	Localities.
Essentially Marine.	Stage E. *Gannister Beds, or Lower Coal-measures.* Thin coals with hard siliceous floors; flagstones and shales. Fossils (marine): Fish (migratory); Mollusca, *Goniatites, Discites, Orthoceras, Posidonomya, Monotis, Aviculopecten, Anthracosia, Lingula*, &c.	South Lancashire, North Staffordshire, North and South Wales.
	Stage D. *Millstone-Grit Series.* Coarse grits, flagstones, and shales, a few thin coal-seams. Fossils: similar to those of the Lower Coal-measures.	Uplands of Yorkshire, Lancashire, and Derbyshire, N. Staffordshire, and N. and S. Wales.
	Stage C. *Yoredale Series.* Shales and grits, passing down into dark shales and earthy limestones. Fossils (marine): including *Goniatites, Aviculopecten, Ctenodonta, Chonetes, Discina, Posidonomya, Productus*, &c.	Uplands and valleys of Lancashire, Yorkshire, Derbyshire, North Staffordshire, Wales, &c.
Essentially Marine (except Stage A in Scotland).	Stage B. *Carboniferous Limestone.* Massive limestone in many beds with intervening shales and grits (thick in the south, thin in the north). Fossils: Fish, Crustacea, Crinoids, Corals, &c.; all marine.	North and South Wales, Derbyshire, Yorkshire, Cumberland; in Scotland the Lower or Main Limestone.
	Stage A. *Lower Limestone Shale and Calciferous Sandstone.* Dark shales in some places; grits, conglomerates, and red sandstone and shales in the northern districts. Fossils (marine).	South Wales, Gloucestershire and Somersetshire, Northumberland and Durham; in Scotland, Calciferous Sandstone series.
	Basis. *Upper Old Red Sandstone.* Yellow sandstones and conglomerates. Fossils (freshwater): not well represented in England.	South Wales, Northumberland, Scotland (Dura Den), Ireland (Kiltorcan).

The above stages contain, in all, about 500 genera and 2400 species. I purpose showing their numerical value and relation one to the other in the passage of the species through the 8 horizons or stages to the close of the Carboniferous period. The connexion of the Permian rocks with the Carboniferous is not an easy task, small as the fauna is known to be; but I shall reserve this as the basis of my next address, if permitted to do so.

The recent work of the Geological Survey has proved that the greater part of the Calciferous Sandstone of Scotland is the equivalent in time of the true Carboniferous Limestone of England. Most of the Carboniferous Limestone of Scotland is the equivalent in time of the Yoredale rocks of Yorkshire; so also is most of that part of the Carboniferous Limestone series of Northumberland from which lists of fossils have been published. In fact the terms Calciferous Sandstone, Lower Limestone Shales, Carboniferous Limestone, and Yoredale Rocks must really be regarded as representing conditions of depth and deposit, and not, when comparing different areas, as representing relative age. I have had great difficulty in dealing with the Yoredale species, as well as those from the Lower Limestone Shales, arising from the terms "Lower Limestone" of the north of England and Scotland and Lower Limestone Shale of the South-west of England and South Wales not being always applied to the same horizons by different authors. Physically in South Wales, Gloucestershire, and Somersetshire they can be definitely traced and mapped, carrying with them an unmistakable suite of fossils, differing essentially from the Great, or Scaur, or Carboniferous Limestone above; entirely destitute of many zoological groups, especially the compound Actinozoa, the Bryozoa, and the Cephalopoda; abounding in fish-remains, chiefly Placoidei (teeth and spines).

The comparison of the Northumberland, Durham, Yorkshire, and Lancashire rocks amongst themselves, and further correlation with the Scotch series, has yet to be effected; but the three groups in the table at p. 226 (viz. the Lower Limestone shales, the Carboniferous Limestone, and the Yoredale rocks) present, as nearly as possible, the census of species as now received and recorded.

In the Pendle and Clitheroe area the Yoredale rocks are of great thickness, 3000–4000 feet; they are scarcely represented in Scotland, although so near; whilst the great or "Scaur-limestone" of Derbyshire is represented in Northumberland. The probable arrangement and agreement of the North-of-England and Central-Scottish stages have been arranged or correlated by Mr. Hull, through a tacit agreement with Professor Geikie and Mr. Lebour, both on stratigraphical and palæontological grounds. The stages are as follows:—

	North of England.		Central Scotland.
Stages E.	Gannister beds.	E.	Slaty-black-band series.
D.	Millstone Grit.	D.	Moorstone-rock series.
C.	"Great Limestone." Flagstone and Shales.	C.	Upper Limestone series. (Yoredale beds.) Lower Coal-and-Ironstone series.
B.	"Scaur-Limestone series."	B.	Lower Limestone series.
A.	Sometimes absent. ("Tuedian.")	A.	Calciferous Sandstone series.

Mr. Lebour, in corroboration of this, compared lists of fossils from the "Great Limestone" of Northumberland ("the most marked

Yoredale bed") with the prepared Scotch list, and found that 32 species were not known in Scotland, and that about 60 species ran through or were common to the three Scotch divisions, and also that 28 were found in the Scotch upper and middle series only, 10 being found only in the lower series. This community of 28 species corroborates Mr. Hull's views, who believes that geographical position, through an interposed Silurian barrier, separated the Scotch and English marine areas. There can be no doubt also that over the whole of the north of England and the borderland of Scotland shallow-sea, estuarine, and land conditions largely prevailed during the earlier, if not the middle, Carboniferous stages. It is by such conditions that correlation is rendered difficult over extended areas; and only by patient, long-continued work with a definite end or purpose, changes both on the dip and strike being carefully mapped or recorded, can the subdivision of one region be actually compared with that of another. It is from this want of uniformity in working that various horizons are adopted for the same beds by different authors, and that ranges of fossils are made to differ also. A very important table is appended to Mr. Hull's paper, giving the census or known fauna and vertical range of the marine genera and species of the Gannister beds (stage E). All these species are embodied in the numerical estimate in my own table. 36 genera and 69 species are enumerated by Mr. Baily; all the genera and 40 species ascend upwards or come from the underlying Carboniferous Limestone. Mr. Baily determines that only 6 species of the 69 pass to Stages F and G. They are *Goniatites Listeri*, *G. Looneyi*, *Conularia quadrisulcata*, *Aviculopecten papyraceus*, *Discina nitida*, and *Productus scabriculus*. No marine shells occur in the Upper Coal-measures in the table, *Spirorbis carbonarius* and *Anthracosia* only characterizing the Stage G. Baily also states that 18 species are peculiar to Stage E, or the Gannister beds *.

Professor Hull in his paper gives a table of the "Continental equivalents of the British Carboniferous divisions," and a table also of "Representative Carboniferous formations," both of great use in classification. A fourth table is added, showing the vertical range of the marine genera and species of Stage F (Middle Coal-measures).

PLANTÆ.—Large as the Devonian flora of America appears to have been, it bears no comparison with the succeeding Carboniferous group, either in America, Britain, or Europe. 95 genera and about 320 species constitute the whole of the known Devonian Plantæ, through the universality of their distribution. That much of the Carboniferous flora was derived from the Devonian is evident. Of the 84 British Carboniferous genera, 36 occurred in the Devonian, and these are also the most typical or marked in the Carboniferous system.

We owe our chief knowledge of the Devonian and Carboniferous flora of North America to Dr. Dawson, of Montreal, Vanuxem, Hartt, Rogers, Lesquereux, Newberry, and others, who have largely added to the literature of the fossil flora of the American Continent.

* Quart. Journ. Geol. Soc. vol. xxxiii. pp. 613–651.

The British Devonian flora is small, including only 12 genera and 18 species, as stated in the Devonian table. The American genera and species of the Carboniferous flora number, according to the published lists &c., 94 genera and 695 species; and the European Carboniferous flora, including the British, 176 genera and 1370 species; the species occurring in the 8 divisions of our Carboniferous strata number 339, illustrating 84 genera. The stratigraphical distribution is as follows:—

Calciferous Sandstone	10	genera and	12	species.
Lower Limestone Shale	22	„	44	„
Carboniferous Limestone	13	„	22	„
Yoredale Rocks	none	„	none	„
Millstone Grit	10	„	27	„
Lower Coal-measures	54	„	211	„
Middle „	34	„	128	„
Upper „	33	„	168	„

Ten genera are largely represented in Britain, and contain 192 species out of the 339, forming the whole flora: they are *Alethopteris* 9 species, *Asterophyllites* 11, *Calamites* 14, *Lepidodendron* 21, *Lepidostrobus* 15 (but for the number given, these cones of *Lepidodendron* should be taken as that genus; probably we may never know to what species of *Lepidodendron* all these *Lepidostrobi* belong), *Neuropteris* 23, *Pecopteris* 28, *Sigillaria* 27, *Sphenopteris* 32, *Ulodendron* 12. All the *Alethopterides* are from the Coal-measures. The *Asterophyllites*, with two exceptions (*A. foliosus* and *A. longifolia*), are also Coal-measure fossils. The *Calamites* range from the Calciferous Sandstone to the Upper Coal-measures—4 species, *C. cannæformis*, Schloth., *C. cultranensis*, Haught., *C. dubius*, Artis, and *C. Lindleyi*, Sternb., occurring in and below the Carboniferous Limestone; the remaining 10 are Coal-measure forms and mostly belong to the Lower series. The 21 species of *Lepidodendron*, with 5 exceptions, are all from the Coal-measures, as are 13 of the 15 *Lepidostrobi*; 2 species (*L. comosus*, L. & H., and *L. variabilis*, L. & H.) are Lower Limestone Shale species. With one exception in the genus *Neuropteris* (*N. Loshii*), the species are from the Coal-measures; although we know that *N. cordata*, *N. flexuosa*, and *N. gigantea* are Millstone-Grit forms. No *Pecopteris* is known below the Lower Coal-measures; therefore the large number of species (28) are essentially Upper Carboniferous. Of the 27 species of *Sigillaria* only 2 occur below the Lower Coal-measures, viz. *S. dichotoma*, Haught., and *S. pachyderma*, Brongn., which occur in the shales at the base of the Carboniferous Limestone. 3 species of *Sphenopteris* (*S. affinis*, *S. linearis*, and *S. trifoliata*) range from the Calciferous Sandstone to the Coal-measures; 4 others (*S. bifida*, L. & H., *S. crassa*, L. & H., *S. elegans*, Brongn., and *S. obovata*) occur in the Carboniferous shale and limestone; the remaining 25 species irregularly range through the Lower, Middle, and Upper Coal-measures. *Ulodendron minus* and *U. parmatum* range from the Carboniferous shale to the Upper Coal-measures. *U. Lindleyanum*, *U. majus*, and *U. minus* are the Millstone-Grit species. The above 10 genera were selected on account of their being largely represented specifically. Regarding the distribution of the Carboniferous flora, we know that many species occurring in Pennsylvania and Nova Scotia are identical with European and British species. This points to a greater similarity and equality of climate than now prevails, and also to the possible connexion of the coal-bearing areas of Europe with that of America, either by continuous land or by groups of islands.

It is difficult in all cases to determine from the often somewhat vague descriptions of authors the true geological horizon of the many species in the true Coal-measures, or whether they are Upper, Middle, or Lower Coal-measure forms. Every care, however, has been taken to determine this when possible, not only for the Plantæ but for the whole fauna also.

Protozoa: Spongida.—The 10 genera and 15 species known are confined to the Carboniferous Limestone and shales below. The genus *Palæacis* of Haime (1860) now embraces Phillips's *Hydriopora*, M'Coy's *Astræopora*, Seebach's *Palæacis*, and the genus *Sphenopoterium* of Meek and Worthen. The 3 British species, *P. cuneiformis*, J. Haime, *P. cyclostoma*, Phill., and *P. obtusa*, Meek and Worthen, have a wide geographical range, being almost universally distributed; but none of the 10 genera and 15 species have occurred above the Carboniferous Limestone in any area.

Protozoa: Foraminifera.—14 genera (11 belonging to the Imperforata and 3 to the Perforata), with 48 species, range through the lower portion of the Carboniferous group, but none have yet occurred higher than the Yoredale rocks, where 7 genera and 18 species are found, and only 1 genus (*Stacheia*) is known in the Calciferous Sandstone; 6 species illustrate *Stacheia*, and all range from the Calciferous beds to the Carboniferous Limestone. Our knowledge of this order (Reticularia) of the Rhizopoda in the Carboniferous rocks is due to the labours and researches of Mr. H. B. Brady. 40 species are known from the Carboniferous Limestone. 43 of the 48 species in these rocks are named and described by Mr. Brady in his learned monograph upon the British Carboniferous and Permian Foraminifera in the volume of the Palæontographical Society for 1876.

Hydrozoa.—*Arbusculites* and *Palæocoryne* are the only 2 known genera in this class. *Arbusculites argenteus*, with *Palæocoryne radiata* and *P. scotica* (all three from the Carboniferous Limestone), complete the list.

Actinozoa.—Both the Tabulata and Rugosa are well represented in the Carboniferous rocks, especially the Rugosa. 21 genera fall under that order, and 14 in that of the Tabulata. The genus *Cladochonus* of M'Coy (*Jania* of the same author) and *Aulopora* are the only representatives of the Tubulosa. *Aulopora*, which is probably the young state of *Syringopora*, usually referred to the Tubulosa, must be placed with the Tabulata if so determined. 9 families, 36 genera, and 141 species constitute the Actinozoal fauna. The only 2 families of numerical value are the

Favositidæ, with 5 genera, and Cyathophyllidæ, with 20; the remaining 7 families have only 1 or 2 genera each and but few species. No form of Coral is known above the Yoredale rocks, and only 2 genera and 2 species occur in the Yoredale series, viz. *Favosites tumidus*, Phill., and *Zaphrentis Phillipsii*, M.-Edw. The Calciferous Sandstones yield 3 species, *Alveolites septosus*, Fleming, *Favosites tumidus*, Phill., and *Lithostrotion junceum*, Fleming.

The Lower Limestone Shales (mostly those of the west of England) have yielded 13 genera and 30 species; the nature of the deposit greatly influenced and determined the presence of the species. Nearly all the Corals in the shales are simple forms and dwarfed in habit, certainly more so than those species that lived in clearer and deeper water, where lived most of the compound forms which occur so abundantly in the limestone beds. This difference, under petrological association, is manifest on carefully examining the stratigraphical position of the corals in many localities. The Carboniferous Limestone is coralliferous throughout, and the fullest evidence may be obtained of large and extensive reefs composed essentially or mainly of the Rugosa, *Lithostrotion*, *Lonsdaleia*, species of *Cyathophyllum*, and numerous other species. The Carboniferous Limestone of the British Islands yields every known genus and species catalogued; in other words, 36 genera and 141 species (all the Carboniferous Actinozoa known) are found in the Carboniferous Limestone in one locality or other in Great Britain and Ireland. The whole class culminates in the Mountain Limestone, for only 2 genera and 2 species pass to the Yoredale beds (*Favosites tumidus* and *Zaphrentis Phillipsii*). This sudden termination in time of the Actinozoa was undoubtedly due to those physical changes which took place in consequence of the elevation of the sea-bed and prior to the deposition of the Permian. Our lists, tables, and collections of the Carboniferous Corals have not been studied sufficiently to enable us to construct proper distribution tables; but the accompanying table of 19 of the chief British genera is intended to show their geographical distribution in Britain, also in the chief locality in Europe, and further their correlation with America.

Table showing the numerical value of the species in the chief genera of Actinozoa in Great Britain, Belgium, and America, the former for European, the latter for American comparison.

	England.	Scotland.	Ireland.	Belgium.	America.	Occurrences.
Amplexus	6	4	4	12	5	21
Aulophyllum	2	2	2	...	...	6
Chætetes	4	2	4	2	3	15
Cladochonus	4	...	2	2	...	8
Clisiophyllum	4	5	4	3	..	16
Cyathaxonia	2	1	...	3	6	12
Cyathophyllum	11	5	6	7	3	32
Cyclophyllum	2	2	1	...	...	5
Favosites	6	1	3	5	3	18
Heterophyllia	2	6	...	...	...	8
Lithostrotion	16	10	12	4	5	47
Lonsdaleia	4	2	...	1	1	8
Michelinia	4	2	5	4	1	16
Palæacis	1	2	...	2	...	5
Phillipsastræa	2	...	...	..	...	2
Syringopora	5	3	6	5	4	23
Zaphrentis	8	10	5	21	18	62
	83	57	54	71	49	304

Echinodermata.—The class Echinodermata is represented in the Carboniferous rocks by 4 orders—the Crinoidea, the Blastoidea, the Perischoechinoidea, and the Echinoidea. The Holothuroidea through the Synaptæ occur also in a few localities. 30 genera and 163 species constitute the entire fauna, and the whole are in the Carboniferous Limestone division. Only 1 species (*Archæocidaris Urei*) seems to be known in the Calciferous Sandstone. No species appears in the Yoredale rocks; indeed the entire class ceases to appear above the Carboniferous Limestone, the 5 succeeding divisions being utterly void of this class and the Cœlenterata. The Lower Limestone Shales through 11 genera yield 31 species—*Actinocrinus* 5, *Archæocidaris* 3, *Astrocrinus* 1, *Atocrinus* 1, *Cyathocrinus* 2, *Palæchinus* 3, *Platycrinus* 10, *Poteriocrinus* 3, *Rhodocrinus* 2, and *Taxocrinus* 1 species. Only 1 of the above is special or confined to the Lower Carboniferous Limestone of Carlops, Peeblesshire, *Astrocrinites* (*Zygocrinus*) *Benniei*, R. Ether., jun.

The characteristic genera, and those containing the largest number of species, are:—*Actinocrinus* 21 species, 5 of the 21 occurring in the Lower Limestone Shale; *Cyathocrinus* 10 species, 2 of the 10 are also Lower Limestone Shale; *Platycrinus* 25 species, 10 of which are in the Lower Limestone Shale; *Rhodocrinus* 12 species; and *Archæocidaris* 10 species. The order Blastoidea, through the Pentremitidæ, 16 species, and *Pentaphyllum* 1 species, are all confined to the Carboniferous Limestone proper. The singular group of the Perischoechinoidea, with *Palæchinus* 7 species, *Perischodomus* and *Melonites* 1 each, also essentially characterize the Carboniferous Limestone proper.

Annelida.—34 species of this class, belonging to 13 genera, wander through the 8 divisions. *Spirorbis* numbers 14 species and *Serpula* 6; the remaining 11 genera have only 1 or 2 species each. *Serpulites carbonarius*, *Spirorbis pusillus*, *S. caperatus*, and *S. helicteres* are the only 4 species that range above the Carboniferous Limestone and into the Coal-measures where the argillaceous shales and clays are of marine or estuarine origin. The Calciferous Sandstones of Scotland, through the researches of Bennie, have yielded *Serpulites carbonarius*, *Spirorbis Eichwaldi*, *S. globosus*, *S. helicteres*, *S. pusillus*, and 2 varieties. 16 species occur in the Lower Limestone Shale; 10 genera and 24 species in the Carboniferous Limestone. *Serpulites membranaceus* is the only Yoredale form; and 4 species, *Crossopodia Embletoniæ*, *C. media*, *Serpulites carbonarius*, and *Spirorbis pusillus*, occur in the Millstone Grit; and *Serpulites carbonarius* is the only Lower Coal-measure form, also associated with *Arenicola carbonaria*. The same 2 species are Middle and Upper Coal-measures, which exhausts the Annelidan fauna.

Crustacea.—The remarkable Crustacean fauna that occurs in the Silurian rocks numbers about 320 species, chiefly Trilobites, all of which, with the exception of 5 or 6 genera, died out entirely at the close of the Silurian period. The Crustacea of the Old Red Sandstone belong chiefly to the order Merostomata—*Eurypterus*, *Pterygotus*, and *Stylonurus* being the characteristic genera. The Trilobita, comprising only 6 genera (*Bronteus*, *Cheirurus*, *Harpes*, *Homalonotus*, *Phacops*, and *Phillipsia*), with 11 species, are Devonian, no Trilobite occurring in the Old Red proper. The Carboniferous system in Britain yields 33 genera and 225 species, 130 of which are Ostracoda, 59 Phyllopoda, 2 Merostomata, 6 Pœcilopoda, 2 Stomapoda, 5 Macrura, and 13 Trilobita, illustrating the 3 genera, *Brachymetopus* (2), *Griffithides* (5), and *Phillipsia* (6), which group entirely disappears with the close of the Carboniferous Limestone. Nowhere in Europe or America have we evidence of the continuity of this group above the rocks named. Beyond the Ostracoda and Phyllopoda, which constitute the 2 important orders in the Carboniferous rocks (together numbering 189 species out of the 225 known), there is little to discuss. The genera of Ostracoda number 85, the Phyllopoda 8, the Trilobita only 3.

The Calciferous Sandstone (Tuedian) has yielded 9 genera and 20 species, mostly Ostracoda, and 2 species of *Anthrapalæmon*, the first known appearance of the group or tribe Macrura. (3 other species of the same genus occur in the Coal-measures.)

Lower Limestone Shales.—17 genera and 48 species, also chiefly Ostracoda and Phyllopoda, are individually abundant in the Lower Carboniferous beds (below the Carboniferous Limestone).

Carboniferous Limestone.—159 species are recognized and described from the Carboniferous Limestone proper, illustrating 28 genera out of 33 (or nearly every occurring genus is represented), and the above number of species out of the known 225. The 4 genera wanting in the Limestone are *Anthrapalæmon*, *Belinurus*, *Pygocephalus*, and *Candona*. The Ostracoda number no less than 15 genera and 107 species; the Phyllopoda 8 genera and 36 species; the Trilobita 3 genera and 8 species.

Yoredale Beds.—The Ostracoda through the genus *Bairdia* (6 species) and *Kirkbya* (2); the Phyllopoda through *Beyrichia* (5), *Estheria* (1); and *Griffithides mucronatus* (Trilobita), complete the Crustacean fauna of this horizon.

Millstone Grit.—No Crustacean remains known.

Lower Coal-measures.—13 species of Ostracoda, 8 of Phyllopoda, and 4 Pœcilopoda, with 3 species of the genus *Anthrapalæmon*, a Macrurous Decapod, 2 species of which first appeared in the Calciferous Sandstone (*A. Maconochii*, Ether., and *A. Woodwardii*, Ether.). *A. dubius*, Prestw., *A. Grossarti*, Salt., and *A. Russellianus*, Salt., belong to the Lower and Upper Coal-measures. This is the earliest known appearance of the order Decapoda. This ancient type has been found both in the Coal-measures of Europe and North America. *Anthrapalæmon* is related to the living *Galathea*. Of the suborder Xiphosura or Pœcilopoda we possess 2 genera, *Bellinurus* and *Prestwichia*, this last allied to *Neolimulus* of the Upper Silurian. The Penny-stones of Coalbrook Dale yield *Prestwichia rotundata* (*Limulus*). All the thoracic and abdominal segments in *Prestwichia* are ankylosed. The earliest appearance in time or commencement of existence of the Xiphosura is in the Ludlow rocks; no Xiphosuran has yet been detected in the Devonian. *Pygocephalus Cooperi*, Huxl., and *P. Huxleyi*, Woodw., occur in the Lower Coal-measures. These Podophthalmatous Stomapods, with the Decapod *Anthrapalæmon* (3 species), carry back in time the higher order of the Crustacea.

Middle Coal-measures.—*Anthrapalæmon dubius*, *Bellinurus bellulus*, König, *Beyrichia arcuata* and *B. Binneyana*, *Estheria Beinertiana* and *E. striata*, are all the Crustacea known in the Middle Coal-measures.

Upper Coal-measures.—10 genera and 16 species compose the Crustacean fauna of the Upper Coal-measures—Ostracoda 6, Phyllopoda 7, Pœcilopoda 1, and *Anthrapalæmon Grossarti*.

Number of Species in the six Palæozoic orders of the Crustacea occurring in England, Scotland, and Ireland; also in Belgium and America. The two latter areas for comparison as before.

Orders.	England.	Scotland.	Ireland.	Belgium.	America.
Ostracoda	45	68	38	21	9
Phyllopoda	18	29	14	9	11
Xiphosura	8	1	5	...	2
Eurypterida	1	2	...	...	2
Decapoda	1	7			
Trilobita	13	7	14	15	26
	86	114	71	45	50

Bryozoa.—The Carboniferous Bryozoa as a group constitute by far the largest series in any division of the Palæozoic rocks. 77 species range through the 3 lower horizons of the Carboniferous series, 74 belonging to the true Carboniferous Limestone, 28 to the Lower Limestone Shales or Lower Limestones, and 4 to the Calciferous series; not a single species passes to or occurs in the Yoredale, Millstone Grit, or either one of the three divisions of the Coal-measures. The whole group essentially belongs to and characterizes the Calcareous rocks and shales at the base of the formation; the large genera are—*Ceriopora* 5 species, *Fenestella* 26, *Glauconome* (*Acanthocladia*) 8, and *Polypora* 8. 20 other genera of great zoological value occur, but the species are few in each genus (1 to 4). *Actinostoma*, *Carinella*, *Diastopora*, *Goniocladia*, *Hemitrypa*, *Ptilopora*, *Rhabdomeson*, *Synocladia*, and *Vinculària* are important genera in the Carboniferous rocks, and distinctively determine the age of the beds in which they occur. Be it remembered that none of the Palæozoic genera live on or extend into the Mesozoic period, and the Fenestellidæ become extinct in the Permian rocks. 24 genera and 77 species at present represent the fauna of this division of the Molluscoida; doubtless the species will be much reduced through extended research and critical examination*; but as Mr. Shrubsole is carrying on research in the Fenestellidæ, and Mr. Vine investigating the Diastoporidæ, it is better to give the census of the species as they now stand without incomplete modification. Mr. Shrubsole's last paper is not yet published; I will therefore notice their distribution, subject to the anticipated work of these two authors.

Calciferous Sandstone.—*Archæopora nexilis*, *Ceriopora similis*, *Fenestella Morrisii*, *F. plebeia*, *F. tuberculato-carinata*, and *Glauco-*

* *Vide* the able papers by Mr. Shrubsole, F.G.S., and Mr. G. R. Vine in the 'Quarterly Journal of the Geological Society,' vol. xxxvi.; also Vine, 'Report of the British Association,' 1880, "On the Carboniferous Polyzoa," for important matter relative to the history and classification of the Polyzoa.

nome gracilis appear to be all known in these lowest beds of the northern Carboniferous rocks.

Lower Limestone and Shales.—13 genera and 26 species illustrate these shaly limestones at the base of the Carboniferous; the 3 chief genera are—*Fenestella* 12 species (far too numerous), *Glauconome* 3, and *Pustulipora* 2 species; the remaining 9 genera have only 1 species each; many of these, necessarily, also occur in the succeeding Carboniferous Limestone.

Carboniferous Limestone.—72 species occur, belonging to 19 genera; the most important of the latter are—*Fenestella* with 25 species, *Glauconome* 8, *Polypora* 8, *Rhabdomeson* 3, *Pustulipora* 4, and *Ceriopora* 5 species. The 13 remaining genera, although poor in species, are highly characteristic; amongst them may be named *Sulcoretepora*, *Synocladia*, *Vincularia*, *Actinostoma*, and *Diastopora*. No species passes to higher strata or above the Carboniferous Limestone.

Arachnida.—Only in the Lower Coal-measures have we detected the Arachnida, 5 species representing 3 genera—*Architarbus subovalis*, H. Woodw., *Eophrynus Prestvicii*, Busk, *Eoscorpius anglicus*, H. Woodw., and *E. carbonarius*, Meek and Worth.; an undescribed form occurs, which, however, may be *E. anglicus*. *E. carbonarius* is also an American species, occurring in the Coal-measures of Illinois; and *Architarbus* is also a North-American form. The occurrence of two of the three genera and one species in two areas so widely separated is significant, with many other facts, of the probability of the continuity of land between Britain and America during the long period required for the deposition of the Coal-measures and the accumulation of coal.

Myriopoda.—The 2 genera of Chilognathous Myriopoda, *Euphoberia* and *Xylobius*, which occur in our Coal-measures are also American, and, with the Arachnida, again add strong presumption to land-continuity, densely covered with that peculiar flora known to have flourished during the Coal-measure period. We possess 3 species of *Euphoberia*, viz. *E. anthrax*, Salt., *E. Brownii*, H. Woodw., and *E. ferox*, Salt. Dr. Dawson's genus *Xylobius*, also the known American species "*Sigillariæ*," lends additional interest to the attempt to correlate our fauna and flora of the Coal-measures with those of the American continent; for many species of plants are identical, and with them associated faunal groups.

Insecta.—Both the Orthoptera and Coleoptera are represented in our Coal-measures. The Mantidæ through the genus *Lithomantis* of Dr. H. Woodward, the Locustidæ through *Gryllacris*, Swinton; these two genera belong to the Orthoptera. The genus *Curculioides* of Dr. Buckland belongs to the Coleoptera. These all occur in our Lower Coal-measures. Their history and zoological affinities have been ably described by Dr. H. Woodward, F.R.S., in the 'Journal' of our Society (vol. xxxii.); doubtless every fresh investigation into the rocks that hold and yield the extinct flora of our coal-fields will bring to light the remains of the three last groups, the Arachnida, Myriopoda, and Insecta; they are, or were, intimately associated with the vegetation of the Carboniferous epoch, and, with other remains in the same rocks, show that the Atlantic ocean covers a vast area of once continuous or contiguous land.

Every one who has studied the varied conditions of the Carboniferous series, the deposition of its strata, the distribution of its fauna, will at once admit that its history is only to be written through the great and reliable group of the Mollusca (Brachiopoda, Lamellibranchiata, Gasteropoda, Pteropoda, Heteropoda, and Cephalopoda), whose 6 divisions or classes number 116 genera and 1020 species, or nearly one half the entire known Carboniferous fauna. So many of the genera have come down to the present day, that inferentially, through observation, we know their habits in Carboniferous times; they show us that, during or throughout the accumulation of the Carboniferous Limestone, moderately deep-sea conditions prevailed, and the Molluscan fauna then surpassed all subsequent numerical development during the Carboniferous period. Ultimately physical changes caused the sea to shallow, thus altering all bathymetrical conditions at the same time: littoral species died out, through altered circumstances; and the habits of the deeper-sea fauna changed also on slow elevation, the zonal lines of life undergoing modification through adaptation. Plainly are these modifications and changes to be observed through the several stages, from the Calciferous Sandstones to the summit of the Coal-measures. Zoologically, only the last five stages of the Carboniferous group have to be considered, as so great a change took place at the close of the Gannister group or Lower Coal-measures, the succeeding beds illustrating terrestrial conditions through the rich and earliest extensive flora known (*vide* Table at end of Carboniferous system, p. 226). No one has felt the difficulty of showing the distribution of life through the Carboniferous group more than myself, the rich fauna that characterizes the series from the Calciferous Sandstones to the top of the Gannister (or Lower Coal-measure) beds being most difficult of analysis.

Every extended sea-bed has its own conditions and its own fauna; the exact nature of that sea-bottom it is difficult to predicate; it can only be learnt through examination. Admitting that the fauna of any group of rocks is, or was, as local as the physical conditions during deposition, and the maximum of life is usually local, it will show itself in any area, in any part of an epoch or of a stage; it is governed chiefly by the nature of the sediment and by temperature. The questions of *appearance* of species, *duration*, *migration*, *extinction*, *recurrence*, and many other conditions that govern marine life in all its phases are to be studied through a careful investigation of the physical history of the Carboniferous rocks; and through no other zoological group do we receive so much instruction as through the Mollusca.

Brachiopoda.—Both the Tretenterata, or "Inarticulata," and the Clistenterata, or "Articulata," are largely represented in the Carboniferous rocks; and many genera appear for the first time, and essentially characterize the lower members of the Carboniferous group: such are *Hypodema* and *Syringothyris*, neither of these appearing in older strata.

The specific development of *Productus* has no precedent or parallel in any other group of British strata. 44 species occur in the deposits from the Calciferous Sandstone to the Lower Coal-measures, 5 species in the Calciferous series, 16 in the Lower Limestone Shale, 41 in the Carboniferous Limestone, 7 in the Yoredale, 5 in the Millstone Grit, 3 in the Lower Coal-measures, 1 in the Middle Coal-measures (*P. scabriculus*), and none in the Upper Coal-measures; the genus (but no known Carboniferous species) passes to the Permian rocks, and is represented by *P. horridus*, its last appearance.

The genus *Spirifera* attains its highest development in this horizon also; 30 species range side by side by with the *Producti*; and it is well to state also their numerical value in the several horizons: Calciferous Sandstone 3 species, Lower Limestone Shale 17, Carboniferous Limestone 30, Yoredale rocks 6, Millstone Grit 4, Lower Coal-measures 4. 2 of the 30 species of *Spirifera* are Devonian, *Sp. lineata* and *Sp. Urii*; thus 28 species are new to Britain; and no less than 185 species (British, European, and American) have been described. The *Rhynchonellæ* of our Carboniferous rocks number 21 out of the 30 European species; and 18 of them are new; the 3 derived from the Devonian are *R. pleurodon*, *R. pugnus*, and *R. reniformis*.

The genus *Terebratula* begins here to be numerically abundant, no species being known in the Silurian strata, and the Devonian rocks yielding only 4 species, whilst 7 species are Carboniferous. The great development of this genus in the Jurassic rocks surpasses that of all other Clistenterata; in our own area they apparently nearly died out or migrated after the Carboniferous epoch, none occurring in the Trias. The genus *Athyris* ranges from the Calciferous Sandstones to the Lower Coal-measures; *A. ambigua* and *A. planosulcata* are the only species that transgress the Carboniferous Limestone. The genus *Atrypa* was formerly recognized as a Carboniferous genus with 26 species, which are now relegated to *Rhynchonella*, *Retzia*, and *Athyris*. *Camarophoria*, with its 5 species, belongs to the Carboniferous Limestone; only *C. crumena* passes to the Permian, omitting the 5 intermediate stages or horizons. *Chonetes*, only in one instance (under the species *hardrensis*), ranges above the Carboniferous Limestone into the Lower Coal-measures, the whole 15 species being otherwise confined to the limestone and the shale below.

The significance or importance of *Productus* as a Carboniferous genus cannot be overlooked when determining through its species definite horizons in these rocks. It is ubiquitous; in no region on the globe, where the Carboniferous rocks are developed, do we not find this characteristic shell and in vast abundance—in the Polar regions, Australia, New Zealand, Van Diemen's Land, India, America (in 15 States), throughout Europe, and in Africa.

The Carboniferous Brachiopoda consist of 20 genera and 175 species; and 7 of the 8 horizons possess them: 9 genera and 18 species occur in the Calciferous Sandstones of Scotland; 11 genera and 80 species range through the thin-bedded Carboniferous Limestone Shales, or the *Lower* Limestones; 14 genera and 172 species have been collected and named from the Carboniferous Limestone alone; 10 genera and 31 species are from the Yoredale rocks and Upper Limestone Shales; 11 genera and 24 species are Millstone Grit; the Lower Coal-measures yield 9 genera and 18 species, and the Middle 3 genera and 3 species. We know of no Brachiopoda in the Upper Coal-measures. The whole group, with every species, has been exhaustively worked out by T. Davidson, Esq., F.R.S., in the volumes of the Palæontographical Society; nothing is left undone by that distinguished brachiopodist, whose labours in this field of palæontology are universal. To Mr. Davidson we are indebted for the highest research into the morphology, history, and classification of this most difficult class of Mollusca.

	England.	Scotland.	Ireland.	Belgium.	America.	Occurrences.
Camarophoria	4	1	3	1	3	12
Chonetes	12	10	13	5	28	68
Crania	2	2	3	2	3	12
Cyrtina	2	...	1	...	...	3
Discina	2	1	2	11	14	30
Lingula	5	4	3	3	8	23
Orthis	7	4	8	8	25	52
Productus	45	32	28	47	109	261
Rhynchonella	17	3	11	11	36	78
Retzia	3	1	1	3	12	20
Spirifera	40	21	30	48	108	247
Spiriferina	3	5	5	3	9	25
Streptorhynchus	4	7	5	3	10	29
Terebratula	4	3	2	8	26	43
	150	94	115	153	391	903

The preponderance of the two genera *Productus* and *Spirifera* is a great feature in the Carboniferous rocks. *Chonetes, Rhynchonella*, and *Orthis* follow in importance so far as the number of species lends significance. *Chonetes* and *Productus* make their first appearance in these rocks, and, with *Retzia*, *Streptorhynchus*, and *Cyrtina*, disappear at the close of the period. 5 genera and 6 species of Brachiopoda pass to the Permian; they are *Camarophoria globulina*, Phill., *C. Schlotheimi*, V. Buch, *Discina Koninckii*, Geinitz, *Lingula Credneri*, Geinitz, *Spirifera Clannyana*, King, and *Spiriferina cristata*; and beyond 2 species of Ostracoda I know no other connecting or transgressive species than the above; in other words, only 8 species of all orders pass to higher rocks out of the Carboniferous system. Even the Rhizopoda (Foraminifera), which have so wide a distribution in time, occur not beyond the limits of this formation.

Lamellibranchiata.—*Monomyaria**. This group and the Dimyaria united number no less than 54 genera and 415 species. The Monomyaria, up to the present time, are represented by 10 genera and 179 species, 103 of which belong to the genus *Aviculopecten*, 28 to *Avicula*, *Pinna* 6, *Posidonomya* 12, *Pterinœa* 4, *Pteronites* 9, *Streblopteria* 3, *Gervillia* 2, *Inoceramus* 4, *Lima* 2, and *Pinna* 6. The Calciferous Sandstones of Scotland and Northumberland have yielded 3 genera (*Avicula*, *Aviculopecten*, and *Pteronites*) and 13 species; the Lower Limestone Shales, or Lower Limestones, 5 genera and 64 species; the Carboniferous Limestone 11 genera and 151 species; the Yoredale rocks 4 genera (*Avicula*, *Aviculopecten*, *Pinna*, and *Posidonomya*) and 14 species; the Millstone Grit 3 genera (*Avicula*, *Aviculopecten*, and *Posidonomya*) and 11 species; the Lower Coal-measures 3 genera (the same) and 13 species; 4 species of *Aviculopecten* occur in the Middle Coal-measures; and 1 (*Aviculopecten papyraceus*) is the only form in the Upper Coal-measures. The species having the longest range are *Aviculopecten alternatus*, *A. gentilis*, *A. granosus*, *A. papyraceus*, *A. quadratus*, *A. scalaris*, and *A. variabilis*, *Posidonomya Becheri*, *P. lateralis*, and *P. membranacea*. The species of the genera *Pteronites*, *Pterinœa*, *Streblopteria*, *Posidonomya*, *Pinna*, *Avicula*, and most of the *Aviculopectines* are chiefly from the Carboniferous Limestone. We may assume that the largely represented group of the Aviculopectinidæ possessed much the same bathymetrical range as that of the genus *Pecten* in our modern seas; the same with *Pinna* and *Posidonomya*. Indeed it would appear, from the persistency of the vertical range of the group Monomyaria, that no general depth governed their habit; for only 14 species out of the 179 range above the Carboniferous Limestone and Yoredale beds. 10 are named above; and the following 4 may complete the species—*Aviculopecten fibrillosus*, *A. obtusus*, *Posidonomya Gibsoni*, and *Pinna spatula*. The Table also expresses the number of species that are in the Millstone Grit and Coal-measures included here. The magnitude of the Monomyarian group is sufficient reason for treating it separately, especially considering that one genus alone (*Aviculopecten*) is represented by 103 species.

* I retain this term here, including in it only the Asiphonida, represented by the Ostreidæ, Aviculidæ, and Pectinidæ.

	England.	Scotland.	Ireland.	Belgium.	America.
Anomia	...	2	1		
Avicula	16	10	23	25	24
Aviculopecten	48	50	80	33	40
Gervillia	4	...	2	...	5
Inoceramus	...	...	4	1	1
Lima	...	...	2	...	1
Pecten	...	...	1	...	6
Pinna	5	4	5	3	6
Posidonomya	8	2	8	5	9
Pterinæa	1	...	3	...	9
Pteronites	3	6	7	...	2
	85	74	136	67	103

The preponderance of species in one genus, as in *Aviculopecten*, is unexampled in any other British formation. 150 species occur in Britain and Europe; 50 have been described from America, and all differ from our forms. The species occurring in the Belgian Carboniferous rocks are known to us through the researches of De Koninck. In Ireland, mainly through the researches of M'Coy and Baily, the Integropallialia appear to have been exhaustively recorded. The genus *Avicula*, in the Irish Carboniferous rocks, numbers about 23 species, *Aviculopecten* 80, *Pecten* 5, *Pteronites* 5, *Posidonomya* 8, *Pterinœa* 3, *Pinna* 5. Scotland: *Avicula* 10, *Aviculopecten* 50, *Pinna* 4, *Posidonomya* 2, *Pteronites* 6. England: *Avicula* 16, *Aviculopecten* 48, *Pinna* 5, *Posidonomya* 8, *Pteronites* 3, and *Pterinœa* 1. These comparisons are important, as showing geographical distribution as well as age. The collective fauna illustrating this group in all Europe beyond Belgium does not exceed 50 species, showing either want of research or the small development of the Carboniferous rocks east of Rhenish Prussia.

LAMELLIBRANCHIATA.—*Dimyaria**.—No less than 43 genera and 245 described species occur in the Carboniferous rocks, the largest number being in the Carboniferous Limestone (30 genera and 182 species); the underlying Lower Limestone and Shales yield 23 genera and 103 species; and the Calciferous beds of the north of England and Scotland 17 genera and 38 species; only 9 species are Yoredale. Many species are necessarily common to the three lower horizons; but the faunal contents are as stated. The Coal-measure species will be noticed in their place.

Thus the united British Lamellibranchiate (or Pelecypod) fauna numerically reaches 54 genera and 424 species, 179 being Monomyarian Asiphonida (Integropallialia) and 245 Siphonida (Sinupallialia). Hitherto I have not mentioned the Coal-measure Dimy-

* 18 families, including the Arcidæ, Trigonidæ, and Unionidæ.

aria, or those occurring in the Millstone Grit and Lower, Middle, and Upper Coal-measures. With the exception of the Lower Coal-measures, which have yielded 12 genera and 42 species, the three remaining horizons are comparatively poor, as would be anticipated from the estuarine condition or nature of the deposits. *Anthracosia, Anthracoptera, Axinus, Ctenodonta, Edmondia, Modiola, Myacites, Myalina,* and *Schizodus* are the genera that characterize the Coal-measures, or beds above the Yoredale series.

6 genera and 9 species are all that are known from the Millstone Grit; the genera are *Anthracosia* 2 species, *Axinus* 1, *Ctenodonta* 3, *Edmondia* 1, *Lunulacardium* 1, *Myacites* 1.

The genera in the Lower Coal-measures, 14 with 44 species, are still more estuarine in habit, many allied to the Unionidæ and Myadæ—*Anthracomya* 5 species, *Anthracosia* 6, *Anthracoptera* 2, *Axinus* 2, *Conocardium* 1, *Ctenodonta* 6, *Edmondia* 3, *Leptodomus* 1, *Modiola* 4, *Myacites* 4, *Myalina* 6, *Pleurophorus* 1, *Pullastra* 1, *Schizodus* 2. The Middle Coal-measures have, as yet, only yielded 4 genera and 16 species—*Anthracomya* 6 species, *Anthracosia* 6, *Anthracoptera* 2, and *Myalina* 2 species. The Upper Coal-measures contain the same 4 genera with 11 species. The above, with the table of distribution, clearly shows the changes from the deeper-sea fauna of the Limestone series to the shallow and estuarine accumulations of the Coal-measures, the gradual dying-out of those genera, essentially dwellers in clear and deep water and with associated sedimentary matter, as well as the almost total extinction of the molluscan fauna with the elevation of the sea-bed, a few genera only living on into the Permian sea.

The accompanying Table gives the numerical value of the species of 18 of the chief Dimyarian genera out of 43 for England, Scotland, and Ireland; also Belgium, for comparison, which is the only country in Europe where the Carboniferous rocks (Lower series) are well developed. The researches of Prof. De Koninck, of Liége, have afforded me data for this column. I have before stated the small number of known species in the European area beyond Belgium; to show, however, the relationship between the American fauna and our own, I have appended a column also, which shows excess in the number of species in most of the genera. Such holds good with the older Palæozoic genera also; but, through the flora and Mollusca of the Coal-measures, America and Scotland are intimately associated, and, in a similar but less degree, Ireland.

Table of 18 of the chief Carboniferous Genera, showing their specific or numerical value through the five areas or countries named.

Genera.	England.	Scotland.	Ireland.	Belgium.	America.	Occurrences.	
Allorisma (Myacites)	6	3	4	...	28	41	
Anthracomya..................	8	2	1	...	2	13	Chiefly Coal-measures (6 species).
Anthracosia	10	9	...	23	8	50	Ditto (6 species).
Arca	4	6	10	17	7	44	
? Astarte	...	...	...	10	1	11	
Cardiomorpha	9	6	5	36	13	69	
Conocardium	6	2	10	8	13	39	
Ctenodonta	11	15	15	9	34	84	6 Coal-measures.
Cypricardia	7	9	10	16	11	53	
Edmondia......................	10	10	12	2	25	59	3 Coal-measures.
Modiola........................	10	8	12	...	5	35	4 Coal-measures.
Mytilus	3	2	3	30	6	44	
Myalina........................	6	9	1	3	18	37	6 Coal-measures.
Sanguinolites..................	10	10	16	5	27	68	
Schizodus	3	8	7	...	13	31	2 Coal-measures.
Sedgwickia	...	2	7	...	6	15	
Solemya........................	3	...	1	5	5	14	
Solenopsis	...	1	1	7	...	9	
	106	102	115	171	222	716	

Solenoconchia.—6 species of *Dentalium* are known; but none pass above the Carboniferous Limestone. *D. priscum* is the only species that occurs in 3 horizons—the Calciferous Sandstones, Lower Limestones, and Carboniferous Limestone. *D. scoticum* is only found in the Calciferous Sandstones; the remaining 4 belong to the Carboniferous Limestone, and do not range higher.

Gasteropoda.—223 species and 29 genera, all belonging to the division Holostomata of the order Prosobranchiata, constitute the univalve fauna of the Carboniferous rocks. All the genera (29) and 202 species occur in and range through the Carboniferous Limestone; or nearly every species occurs in this horizon. 16 of the 29 genera are distributed through the Carboniferous rocks of Europe and America, and are therefore of zoological as well as stratigraphical value. I give the following Table of these genera to accompany that showing the distribution of the Lamellibranchiata (Dimyaria); by comparison with the molluscan fauna of Europe and America we may hope to obtain some clue relative to the migration and dispersion of the Mollusca from some original area. These 16 chief genera are represented in England by 176 species, in Scotland by 90, in Ireland by 111, in Belgium (chiefly through De Koninck) by 176, and in the American Carboniferous rocks by nearly 200 species. This generic relationship with America is important as determining similarity of bathymetrical conditions, temperature, and food, and connexion through coast-line or land now lost. 9 genera and 21 species occur in the Calciferous Sandstone—*Euomphalus* 4 species, *Lacuna* 1, *Littorina* 2, *Loxonema* 2, *Macrocheilus* 4, *Murchisonia* 3, *Natica* 1, *Naticopsis* 1, *Pleurotomaria* 3.

The Lower Limestone Shales contain 50 species, which, with one exception (*Turbo appropinquans*), are also those of the Carboniferous Limestone above; or 49 of the 50 occur also in the massive limestones.

The Yoredale beds (the Upper Limestone Shales of some authors) are poor in Gasteropoda; only 7 genera and 10 species appear to be known. Clearly this must be the result of imperfect collecting rather than of almost total absence of species. We know that both the Lower and Upper Limestone Shales are impure argillaceous limestones, and not favourable to the presence of the Mollusca at the time of deposition or to the preservation of organic structure afterwards: but we see here the 7 genera only represented by 10 species; they are:—*Euomphalus catillus*, Sow.; *Loxonema constricta*, Sow.; *Macrocheilus curvilinea*, Phill.; *M. imbricatus*, Sow.; *M. rectilinea*, Phill.; *Murchisonia fusiformis*, Phill.; *Naticopsis plicistria*, Phill.; *Pleurotomaria limbata*, Phill.; *P. tumida*, Phill.; and *Turritella tenuistria*, Phill. The Millstone Grit, as we should expect, contains but a small Gasteropod fauna; such arenaceous deposits suit not the habits of this group of Mollusca; only 3 genera and 3 species are known—*Natica variata*, Phill.; *Pleurotomaria limbata*, Phill.; and *Murchisonia fusiformis*, Phill. The Pelagic Cephalopoda in the same beds, as we shall see, number no less than 33 species; but the sandy and muddy beds of the shore was not their habitat; they are not such good witnesses in the beds in which they are found as the ordinary Lamellibranchiata and Gasteropoda. The Lower Coal-measures alone yield Gasteropoda; none are known either in the Middle or Upper. 7 genera and 19 species are recorded from this division:—*Euomphalus Gloveri*, Brown; *Littorina obscura*, Sow.; *L. solida*, De Kon.; *Loxonema galvani*, Baily; *L. minutissima*, Baily; *L. Oweni*, Brown; *L. reticulata*, Brown; *Macrocheilus*, 4 species; *Natica vetusta*, Sow.; *Naticopsis plicistria*, Phill.; *Pleurotomaria limbata*, Phill.; *P. usocona*, Sow.; *Turritella*, 4 species.

Middle Coal-measures none.

Upper Coal-measures none.

Geographical Distribution of the Gasteropoda through 16 characteristic Genera.

	England.	Scotland.	Ireland.	Belgium.	America.	Occurrences.
Acroculia	6	5	8	13	22	54
Chiton	3	3	4	15	2	27
Euomphalus	20	17	20	20	23	100
Littorina	2	1	...	2	...	5
Macrocheilus	17	8	12	5	19	61
Metoptoma	12	...	...	5	2	19
Murchisonia	15	7	6	19	20	67
Natica	13	9	9	14	16	61
Naticopsis	2	1	3	...	...	6
Patella	7	...	5	6	...	18
Phanerotinus	4	...	3	...	2	9
Platyschisma	5	2	4	1	4	16
Pleurotomaria	46	24	16	59	65	210
Turritella	6	1	4	...	2	13
Turbo	6	1	4	5	...	16
Loxonema	12	11	13	12	20	68
	176	90	111	176	197	750

Pteropoda.—The genus *Conularia* first appears in the Carboniferous rocks in the Lower Limestone Shale, and ranges through all but the Upper Coal-measures. This genus dies out in the Coal-measures. Many of the nodules in the "Penny-stone" of Coalbrookdale contain fine examples of *C. quadrisulcata*, Sow., the only determined species known. An undetermined species occurs in the Calciferous Sandstones of Woodhall, Scotland. America yields 17 species of *Conularia* to our 2; our *C. quadrisulcata* is not known out of Britain.

Heteropoda.—*Bellerophon* and *Porcellia* (the former with 27 species and the latter 4) exhaust the species in the Carboniferous rocks. At no period in Palæozoic times did so many species of *Bellerophon* exist in one horizon. 24 of the 27 species are found in the Carboniferous Limestone; and 6 of these 24 species range higher; they are:—*Bellerophon apertus*, Sow.; *B. decussatus*, Flem.; *B. Dumonti*, D'Orb.; *B. hiulcus*, Mart.; *B. Oldhamii*, Portl.; and *B. Urii*, Flem. 4 species (*B. costatus*, Sow., *B. decussatus*, Flem., and var. *undatus*, Ether., and *B. Urii*, Flem.) are Calciferous or Tuedian species. *B. decussatus*, *B. apertus*, *B. hiulcus*, and *B. Urii* range up to the Middle Coal-measures. 5 species occur in the Lower Limestone Shale; but none are peculiar to those beds. 17 species are essentially Carboniferous Limestone. The Yoredale beds have yielded 4 species—*B. apertus, B. decussatus, B. hiulcus*, and *B. Urii*, all species having a long range. The Millstone

Grit contains the same forms. The Lower Coal-measures yield the same, with the addition of *B. navicula*, *B. Oldhamii*, and *B. Dumontii*; none occur in the Upper Coal-measures—this order, like all others in the Carboniferous series, dying out at its close, not to appear again.

The genera *Bucania* of Hall and *Euphemus* of M'Coy are synonymous with *Bellerophon*. Ireland has yielded 21 species of *Bellerophon*, Scotland 15, England 17, Belgium 25, and America 39 species; only 19 species range through Europe, 8 of them being British; and 14 of these 19 are Russian.

Cephalopoda.—No fewer than 169 species are distributed through the British Carboniferous system. 4 genera and 6 species occur in the Calciferous or Tuedian beds, 5 genera and 22 species in the Lower Limestone Shale, 8 genera and 140 species in the Carboniferous Limestone; 5 genera and 33 species are Yoredale; 3 genera and 30 species are Millstone Grit; 3 genera and 24 species occur in the Lower Coal-measures, 3 genera and 6 species in the Middle Coal-measures, and 1 genus and 2 species in the Upper Coal-measures. These 169 species represent 8 genera—*Actinoceras* 1 species, *Cyrtoceras* 3, *Discites* 17 (subgenus of *Nautilus*), *Goniatites* 59, *Nautilus* 36, *Orthoceras* 48, *Poterioceras* 3, and *Trigonoceras* 2 species.

The accompanying Table of the 8 British genera shows the number of species in each country, including, as in the two prior Tables, Belgium and America for comparison, in which it will be seen that the 169 species, through the 500 occurrences, are thus distributed:—the number of species in the 8 genera in England is 126, in Scotland 63, in Ireland 107, and in Belgium 90. Comparison carried beyond Europe to America, as before, shows generic affinity through 114 species, hardly a single form being British. All Europe, only yields 95 species through 11 areas; research and the accident of our possessing these rocks highly developed is the reason why our molluscan fauna is so extensive.

	England.	Scotland.	Ireland.	Belgium.	America.	Appearances.
Actinoceras	1	1	1	1	2	6
Cyrtoceras	2	3	...	8	5	18
Discites	10	3	14	4	1	32
Goniatites	59	15	32	25	32	163
Nautilus	18	14	21	22	54	129
Orthoceras	33	24	36	29	20	142
Poterioceras	2	3	2	...	...	7
Trigonoceras	1	...	1	1	...	3
	126	63	107	90	114	500

VERTEBRATA.

PISCES.—120 genera and 290 species of fish and 26 genera and 33 species of Amphibia compose numerically the Vertebrate fauna of the Carboniferous rocks. The comparatively rich assemblage of ichthyic remains in the Old Red Sandstone bears no proportion to the great increase and development of this class in the Carboniferous system. Only two orders are represented in the Carboniferous rocks, viz. the Ganoidei and Elasmobranchi (*Placoidei*, Ag.), the Ganoidei through the suborder Crossopterygidæ by 4 of the 6 recognized families, the Saurodipterini, Glyptodipterini, Ctenodipterini? (Dipnoi)*, and Cœlacanthini. The Elasmobranchi mainly correspond to the Chondropterygidæ or the Cartilaginous Fishes of Cuvier (the Holocephali and Plagiostomi of Owen and the Selachia of Müller).

The distribution and appearance in time of the two orders appears to have been much the same; the Plagiostomi first appeared in the Ludlow rocks, the Holocephali through the Chimæroids in the Devonian rocks of N. America (genus *Rhinodus* of Newberry). The section Cestraphori of the order Plagiostomi is abundantly represented in the Carboniferous rocks from base to summit, spines and teeth of the several genera occurring everywhere, although very locally, the *Ctenacanthi*, *Gyracanthi*, *Homacanthi*, *Oracanthi*, *Onchi*, and *Leptacanthi* being the most important, and occurring as spines (Ichthyodorulites).

The genera or groups illustrated by palatal and other teeth are *Cochliodus*, *Deltodus*, *Psammodus*, *Petalodus*, *Otodus*, *Ctenoptychius*, *Cladodus*, *Glossodus*, *Diplodus*, *Helodus*, &c. Many of these generic groups will be greatly reduced under stricter and more complete research. My duty here is not to criticise, but rather to bring together for a special purpose the labours of others as at present received.

The lowest recognized rocks of the Carboniferous system, the "Calciferous Sandstone" of the Scotch geologists, or Tuedian of Northumberland, confined to the north of England and south-eastern Scotland, contains 13 genera and 14 species—*Cladodus* 1 species, *Ctenacanthus* 1, *Ctenodus* 1, *Ctenoptychius* 1, *Diplodus* 1, *Eurynotus* 1, *Megalichthys* 1, *Nematoptychus* 1, *Pœcilodus* 1, *Pygopterus* 1, *Rhadinichthys* 1, *Rhizodus* 2, and *Wardichthys* 1. Thus, with one exception, each genus is represented only by 1 species. Surely much has to be done both with the Ganoidei (8) and Placoidei (5) when better materials come to hand; for many of the genera must be established upon slender grounds.

THE LOWER LIMESTONES AND SHALES have yielded 29 genera and 50 species; and if this lower member be associated with the thick or

* I am aware that Dr. Traquair would remove the Glyptodipterini from the Crossopterygious Ganoids and place them sectionally in the order Dipnoi (*vide* Trans. Roy. Soc. Edinb. vol. xxvii. for the sections and families proposed by Dr. Traquair).

true Carboniferous Limestone, the two together would represent 80 genera and 170 species, 17 genera and 22 species being peculiar to the Lower Limestone Shales. No one can doubt that these dark, impure, argillaceous limestones were the commencement of the purer calcareous series above; and palæontologically they cannot be separated. Closer research will probably show that the 17 genera now known to occur only in the Lower Limestones exist in the succeeding series.

Carboniferous Limestone.—This finely developed group of rocks in the British Islands, which has received so much attention both under geological and palæontological aspects, is possibly better understood than any other division of the Carboniferous system. The limestone beds known as the Mountain Limestone have yielded no less than 63 genera and 147 species of fishes; but the Yoredale series which succeed them yield none; and only 3 genera and 3 species are known in the Millstone Grit (*Megalichthys Hibberti, Rhizodus Hibberti*, and *Acanthodes Bronni*). This sudden cessation or non-occurrence can scarcely be accounted for on lithological grounds, or original sedimentary accumulation, such as would be applicable to the habits of certain genera of the Mollusca. Bathymetrical conditions may have influenced this paucity in the whole fauna of the Yoredale and Millstone Grit, which is so apparent on inspection of the Table of Distribution. 38 genera of Placoidei are confined to the Carboniferous Limestone; and 12 genera of the same order are from both Lower Limestone Shale and Carboniferous Limestone: on the other hand, it is remarkable that only 6 genera of Ganoidei are strictly or essentially confined to that horizon; they are *Acrolepis, Asterolepis, Coccosteus*?, *Cycloptychius, Phyllolepis*, and *Platycanthus*. (I give them as near the truth as possible, as the species of Ganoidei in the Carboniferous system are in as much confusion as the Placoidei*.) As before stated, the Yoredale rocks (Upper Limestone Shale of some areas) have not yielded remains of fishes. We are in doubt as to the real position of the Upper Limestones of Durham and Northumberland, or what, if any, should be assigned to the Yoredale group. Nevertheless I am not aware of any Vertebrata occurring in the Yoredale beds. The Millstone Grit, as before stated, has only (so far as I know) yielded 3 genera and 3 species, and these in the form of scales.

Lower Coal-measures.—Whatever conditions caused so complete a break in the distribution of the fishes in our area zoologically, stratigraphically, and geographically during the deposition of the rocks mentioned, the return of the same genera and many of the same species in the Lower Coal-measures is equally important. We have evidence of the remains of 52 genera and 112 species, the whole composed nearly equally of the orders Placoidei and Ganoidei. The numbers may be thus expressed:—In the Lower Coal-

* The Ganoid Fishes are under revision by Dr. Traquair, whose accurate knowledge of the order will be brought to bear upon their structure and classification.

measures 32 genera and 50 species of Ganoidei occur, in the Middle Coal-measures 5 genera and 6 species, in the Upper Coal-measures 6 genera and 8 species. The Placoidei are represented in the Lower by 22 genera and 40 species, in the Middle by 10 genera and 14 species, and in the Upper by 6 genera and 8 species. Regarding the Coal-measure fishes as a whole, however, they stand in the Table as Lower Coal-measures 52 genera and 112 species, Middle 14 genera and 20 species, and the Upper 12 genera and 14 species. The numerical distribution for Britain and Belgium is—

England	136 species.
Scotland	152 ,,
Ireland	120 ,,
Belgium	50? ,,

The Carboniferous system is finely developed in Belgium. 37 of the same genera occur in the American rocks, 10 being Ganoidei and 27 Placoidei, the two orders there yielding 240 species.

Amphibia.—Of the 4 orders in the class Amphibia, the Labyrinthodontia alone occur in the Carboniferous rocks. 26 genera and 33 species are known in Britain. Without exception they all occur in one or the other of the divisions of the Coal-measures.

Prof. De Koninck, in his great work ('Ann. du Mus. Roy. d'Hist. Nat. de Belg.' tome ii., Faune du Calc. Carb. de la Belg. pt. i.), has described 29 genera and 44 species, all from the Carboniferous Limestone. The fauna of the Coal-measures in Belgium is small compared with that of Britain.

The Lower-Coal-measure genera are *Amphicœlosaurus*, *Amphisaurus*, *Anthracerpeton*, *Brachyscelis*, *Batrachiderpeton*, *Discospondylus*, *Dolichosoma*, *Erpetocephalus*, *Ichthyerpeton*, *Keraterpeton*, *Lepterpeton*, *Loxomma*, *Ophiderpeton*, *Labyrinthodontosaurus*, *Leptognathosaurus*, *Macrosaurus*, *Megalocephalus*, *Orthosaurus*, *Parabatrachus*, *Pholidogaster*, *Streptodontosaurus*, and *Urocordylus*.

The Middle-Coal-measure genera are only 3—*Anthracosaurus*, *Megalerpeton*, and *Pholiderpeton*.

Loxomma and *Pteroplax* occur in both Lower and Upper Coal-measures.

We are chiefly indebted to Professors Huxley and Miall for elaborate researches into the structure and affinities of the extinct order Labyrinthodontia, a group eminently characteristic of Carboniferous time; for, with the exception of *Rhinosaurus* from the Lias and the Jurassic *Brachyops*, no remains of this order have hitherto been discovered in rocks younger than the Trias.

Table XVI.—*Carboniferous.*

From Devonian.	Classes.		Genera.	Species.	Calciferous Sandstone.	Lower Limestone Shales &c.	Carboniferous Limestone.	Yoredale beds.	Millstone Grit.	Lower Coal-measures.	Middle Coal-measures.	Upper Coal-measures.	Species that pass to the Permian.
2/2	Plantæ		84	339	10/12	22/44	13/22	...	10/27	54/211	34/128	33/168	
	Protozoa ...	Spongida	10	15	...	2/2	8/12						
		Foraminifera	14	48	1/6	10/29	13/40	7/18					
	Hydrozoa		2	3	...	1/2	2/2						
1/1	Actinozoa		36	141	3/3	13/30	36/141	2/2					
3/6	Echinodermata		30	163	1/1	11/31	31/160						
	Annelida		13	34	2/7	6/16	10/24	1/1	3/4	1/1	1/3	1/2	
1/1	Crustacea		33	225	...	17/48	28/159	5/34	...	12/36	4/6	10/16	1/2
	Arachnida		3	5	...	...	...	...	...	3/5			
	Myriopoda		2	4	...	...	...	...	...	2/3	1/1		
	Insecta		3	3	...	...	...	...	...	3/3			
4/4	Bryozoa		24	77	3/4	13/28	20/74						
10/16	Brachiopoda		20	175	9/18	11/80	14/172	10/31	11/24	9/18	3/3	?	5/6
	Lamellibranchiata.	Monomyaria	11	179	3/13	5/64	11/151	4/14	3/11	3/13	1/4	1/1	
4/5		Dimyaria	43	245	17/38	23/103	30/182	6/9	6/9	14/44	4/16	4/11	
	Solenoconchia		1	6	1/2	1/1	1/5						
3/5	Gasteropoda		29	223	9/21	15/50	29/202	7/10	3/3	7/19			
	Pteropoda		1	1	1/1	1/1	1/1	1/1	1/1	1/1	1/1		
1/2	Heteropoda		2	31	1/4	1/5	2/27	1/4	1/4	1/7	1/1		
3/9	Cephalopoda		8	169	4/6	5/22	8/140	5/33	3/30	3/24	3/6		
	Pisces		120	290	13/14	29/50	63/147	...	2/2	52/112	14/20	12/14	
	Amphibia		26	33	...	...	...	...	...	24/28	3/5	3/4	
37/51	....		515	2409	78/150	186/604	320/1651	49/159	43/115	189/525	70/193	64/216	6/8

The Extension of the Older or Palæozoic Rocks below the Newer or Secondary Formations.

The position and extension of the Palæozoic rocks beneath the newer formations of the British Islands is a problem of deep interest, and is now occupying much attention in consequence of the facts brought to light by the numerous trials lately made either for the supply of water or in search of minerals. It may be said that ever since the remarkable trials for water at Harwich and Kentish Town, and also the still more remarkable generalizations (almost predictions) of R. Godwin-Austen, Esq., in 1856*, and Prof. Prestwich in 1872†, with reference to the possible extension of the Coal-measures beneath the south-eastern part of England, the minds of pure geologists have been excited by speculative views, and desires to arrive at some knowledge of the extension or distribution of old land or Palæozoic surfaces, so as to restore to the eastward in England the physical geography of those groups of rocks which now constitute so grand a feature along the western side of England, Wales, and Scotland, but which are lost or covered up beneath the unconformable newer or Secondary rocks. West of long. 1° 30′ the greater part of the exposed rocks are Palæozoic, ranging from the Cambrian to the Coal-measures, their general strike being about N.E. and S.W. East of this meridian are Secondary and Tertiary rocks of great thickness, which doubtless cover the easterly extension of the Palæozoic series towards the European continent. The geographical changes of land and sea must have been numerous from the time of the consolidation of the Cambrian sea-bed to the close of the Carboniferous epoch, the rocks of the latter period being deposited in depressions and valleys of the older, with succession or position due to the removal of the subjacent rocks. With the old and wide extension of these earliest-formed masses we are becoming daily more familiar. Looking at the physical structure of the south-western and north-western parts of the British Islands, and the great mass of the older Palæozoic rocks of North and South Wales, it is evident that from the Cheviots to Cornwall the oldest rocks in Europe are exposed, their eastern extension being hidden. The Northumberland and Yorkshire coal-fields down to the latitude of Nottingham are covered and deeply buried by the Triassic, Jurassic, and Cretaceous rocks. South of Nottingham these old land areas are again exposed; the Charnwood rocks of unknown age, the associated coal-field of Ashby-de-la-Zouch, with the Warwickshire and South-Staffordshire coal-fields stand out like islands in the midst of the great Triassic plain of mid-England; they are the last isolated exposures or remnants of Palæozoic land seen south of the great Penine axis. A line drawn from the Malvern range, due south to the Mendips, and thence to Torquay, will define absolutely the *exposed* line of demarcation between the Palæozoic and Mesozoic rocks. The mass of North and South Wales stands out in bold relief westward

* Quart. Journ. Geol. Soc. vol. xii. pp. 38–46.

† Popular Science Review, vol. xi. p. 241 (1872).

of the Severn valley. The Old Red mountains and older Silurian rocks which border the northern edge of the South-Welsh coal-field, as well as the Devonian promontory of Cornwall and the mass of North Devon, isolated as they appear to be from the unconformity of the Secondary rocks, are only apparently so through the great overlap. Could we uncover and expose the old Palæozoic floors or land-surfaces with all their irregularities, doubtless we should find that the eastern face of the Palæozoic plain would stretch away under the north-eastern and south-eastern counties and the German Ocean, the newer rocks filling up the irregularities in the old land-surface—this denuded plain being either produced by the eroding agency of the Secondary seas during the slow depression of the area they then occupied, or previously sculptured and fashioned into hills and valleys prior to the deposition of the Secondary or Mesozoic rocks. The Irish Sea, the English Channel, and the German Ocean are only hollows in the land occupied by the several seas around the British coasts, any important change in which would alter our relative position to the continent either to the north, the east, or the south, and in case of upward movements, would reveal those accumulations which have gone on since the close of the Glacial epoch. Could the valleys of the North Sea or St. George's Channel, the English Channel, and the German Ocean become again dry land, we should again be restored to and form part of the great European plain or plateau, and those stratigraphical masses that are now abruptly cut off at the coast all round the British Islands would be traced in broken continuity over their once continuous or originally connected area. Further, could we strip off all the Secondary and Tertiary rocks, and reveal or expose the extension of the older or Palæozoic series towards Germany on the east, and France on the south, then the vexed question of the old physical geology and geography (palæography) of Britain and the relation and correlation of our area with that of Europe would be revealed; the once continuous terrestrial surface joining us to Europe, and probably America, on which grew and flourished the flora which furnished the materials of our coal, could be determined; the probable relation of the underlying or partly contemporaneous Devonian to both the Silurian and Carboniferous; the reason for the isolation of the Old Red Sandstone in different geographical areas, marine in one area, freshwater in another—the one with a well-defined base and top, the other having as yet no discovered base, but having a well-defined passage into the Carboniferous; such and a hundred other problems would be solved could this old floor be ours to examine. A rise of a thousand feet would reveal much of all the hidden older land east of long. 2° W., or all eastward of that which extends from the southern termination of the Penine chain and Charnwood Forest; for we now know that as far south as Northampton, and at less than 1000 feet in depth, the Carboniferous Limestone occurs. Still further south, and but little deeper (1184 feet), the Coal-measures have been proved at Burford, in each case yielding the characteristic fossils, the limestone at Northampton being crowded with 2 species of corals, *Lithostrotion irregulare* and *Lonsdaleia floriformis*; the Coal-measures at Burford with *Cyclopteris orbicularis*, *Neuropteris*, and *Pecopteris*. By degrees we are arriving at sufficient data to enable us to judge somewhat of the physiography of these older accumulations or formations and arriving at their distribution. The sources of the oldest sedimentary strata will probably ever remain a mystery; the materials that supplied these oldest British strata have wholly disappeared; the extent, distribution, and dimensions of the Palæozoic series all afford indications and proofs of the vast regions in the north and west which have been thus denuded or washed away.

This brings me to the consideration of the proof of the extension of the Upper Silurian and Devonian rocks eastward of the Malvern chain, the Staffordshire beds (Dudley), and the Bristol Coal-basin, obtained at no less than five places, if not six; the seventh was unfortunately never completed.

The oldest rocks yet touched are the Wenlock; they were determined at Ware, in Hertfordshire, at 795 feet, immediately beneath the Gault, during the process of boring for an extra supply of water for the New River Company. These beds dip at an angle of 40° to the S.E.; consequently their strike is from the N.E. to the S.W.; and probably the Devonians rest upon them in succession, as they are known to occur at Turnford, 7 or 8 miles to the south of Ware, and continuously on to London. No rocks, however, except 1 foot of Lower Greensand ("Carr stone"), came in between the Silurian and the Gault—the Devonian, Carboniferous, and all the Lower Secondary rocks being unrepresented. This feature in the palæogeography of the eastern region of England, long ago anticipated in some form by Austen, Prestwich, and Hull, has now been verified, and the age of the rocks determined. The line occupied by the Wenlock rocks may be higher or nearer to the north than was hypothetically believed by the authors above mentioned, but not more so than the course or strike of the Silurians and Devonians would probably take, having regard to the position of the Malvern, Woolhope, May-Hill, and Tortworth Silurians to the west, although the Ware beds can hardly be referred to the type of Silurian rocks that exists at the places above named. It will therefore be asked whether this Wenlock at Ware is of British or continental type; in other words, can it be correlated with our Welsh or English Upper Silurian, or is it of the Ardennes type? Do they constitute a portion of the Staffordshire (Dudley) or Shropshire (Wenlock) Silurians, spreading away eastwards towards Belgium? or are they a prolongation of the Silurians of Belgium to the west, or a western extension from the continent? In other words, does this Wenlock at Ware belong to the edge of another basin or coast-line, an extension from Western Europe or Scandinavia, or an easterly expansion of the Upper Silurian of the Silurian area? The facies of the fossils and the characters of the rock in all essentials are decidedly British; yet there is much resemblance to the Scandinavian fauna, a prolongation of the rocks containing which is by no means impossible or improbable. On the whole, however, I am inclined to regard the Wenlocks under Ware as part of the continuous and old denuded Upper Silurian surface of those rocks now conspicuously exposed in Herefordshire, Shropshire, and Worcestershire. In direct E. and W. line, and latitudinally, the Wenlock rocks of Malvern, Woolhope, and May Hill may (under the view of continuity) claim connexion; but I regard the Ware fossils as having more affinity with the Wenlock-Edge group, or that series which underlies the western side of the great mass of the Old Red Sandstone.

The fossils also equally resemble those of the Wren's Nest at Dudley, where the dull earthy limestones as well as the crystalline ones (as at Ware) occur. The 33 species of fossils noticed in the cores at Ware are species for species identical with those of the Wenlock Edge or the Wren's Nest (Dudley). Could we remove the overlying Mesozoic series between Ware and Burford, and again expose the Coal-measures known to occur there at the depth of 1180 feet, then should we better understand the thinning-out of the Triassic and Jurassic series eastwards towards this Silurian ridge or plateau. We can hardly now doubt the extension of the Burford Coal-measures, in all probability terminating against the Silurian or Devonian series in the Ware region, at Turnford, and near London.

To what distance rocks of these or older date may occur north of Ware further research alone can decide. We have, therefore, under the so-called London basin an axis of Palæozoic rocks, two divisions of which are known, the Upper Silurian and Devonian. The Ludlow rocks may be expected to occur under or a little south of Hertford; for, as we shall see, the Devonians set in between Ware and Turnford, and probably occupy the entire area between that place and London, where it is now well known they occur under Tottenham Court Road. The boring at Ware was carried down 797 feet and into the Wenlock beds to the distance of nearly 50 feet, or, to give particulars:—Gravel 14 feet, Chalk 416 feet, Chalk-marl 128 feet, Upper Greensand 77 feet, Gault 160 feet, and Lower Greensand (Carr stone) 1 foot; the boring was continued for 50 feet in the Wenlock Limestone, and without the intervention or occurrence of the Devonian. We are thus justified in stating that the old Palæozoic land-surface composed of Devonian and Silurian rocks occupies much of Middlesex and Hertfordshire at the mean depth of 970 feet; they probably extend westward to the exposed Silurian, Devonian, and Carboniferous areas of Cornwall, Devon, and Wales. Harwich, which lies 80 miles to the eastward and 10 miles further north, and probably on the same strike, has revealed Palæozoic rocks at a depth of over 1000 feet; but the age of these Harwich dark clays or shales was never clearly made out. This question of the depth and geographical extension of these oldest rocks is seldom practically tested; for no mineral wealth of sufficient value occurs below the Coal-measures (Upper Palæozoic) to induce trial or experiment; and but for the purpose of obtaining water pure and in quantity, it is questionable if this problem would have been solved (at present at least); had the Lower Greensand occurred in its normal condition as a water-bearing stratum, or even had the Upper Greensand (above the Gault) yielded water in quantity, neither at Messrs. Meux's, at Turnford, nor at Ware should we have touched the undoubted and unequivocal Devonian and Silurian strata. Few give thought to or are aware of the difference that exists in the thickness of rocks of the same age in different yet not very remote localities. In Britain the Cambrian and Lower Silurian deposits are from 20,000 to 30,000 feet in thickness, whilst in Sweden and Russia their representatives or equivalents in time rarely if ever exceed 1000 feet.

This difference is and was probably due to the form and nature of the Pre-Cambrian land on which the newer Cambrians and Silurians were deposited; for there cannot be any doubt that such Pre-Cambrian rocks did and do exist, and were and are widely extended, although concealed over the present known European area, and that their existence was connected with a probable great geographical extension westwards of the British Islands. The plateau governed by the 100-fathom level that surrounds the British Islands is part of this extension, on which all our physical changes have taken place. Probably the crystalline rocks of Scandinavia, parts of North Wales, North-west Ireland, St. David's, and the Hebrides are exposed areas of this Pre-Cambrian stage of the highest antiquity, and were covered on their submerged and denuded masses by the Longmynd, Harlech, and St.-David's rocks, which in their turn were succeeded in some areas by the Lingula-flags, the Tremadoc, and Arenig, life-groups of antiquity so high that we have no formula to express their age, or when life first appeared in the seas of the British Islands. As yet we have no evidence relative to these formations occurring eastward of the Penine chain, of which Charnwood, Ashby-de-la-Zouch, and the Warwickshire coal-field are the most southerly exposures; but we have lately unexpectedly determined the presence of the Carboniferous Limestone below Northampton at the depth of 890 feet*. This has carried still further south the Penine axis, and would lead us to expect that between Northampton and the exposed Coal-measures of Atherston and Nuneaton an extended coal-field may occur. What relation the Burford coal on the south may have is conjectural only; but I am disposed to regard the whole as one greatly extended coal-tract. We must now regard the Carboniferous Limestone of Northampton in longitude 1° 30′ W. as the most easterly known in England; and no Triassic rocks cover this limestone, a few feet only of undeterminable rocks occur between it and the Lower Lias †. Whether the New Red has thinned away entirely here, or it happens to be accidentally absent, is a question; but at Burford on the same strike and relative position there is a considerable thickness of Triassic rocks, and to the N. and N.W. also every-

* In the cores brought up I determined the presence of *Lithostrotion junceum* and *Lonsdaleia floriformis* in abundance.

† The cores brought up are 15 inches in diameter. This great undertaking, as well as those at Turnford and Chatham, were carried on by Messrs. Docwra and Gulland with their new machinery.

where. The Upper Devonian beds were first determined by myself at Messrs. Meux's; they are of the true N. Devon and N. Cornwall Devonian type—dark chocolate-coloured semi-slates containing the characteristic shells *Spirifera disjuncta* and *Rhynchonella cuboides* &c. This discovery solved the problem of the existence of Palæozoic rocks at an accessible depth under London, and of the absence of the Jurassic series. Immediately above the Devonian occurred the Lower Greensand, abnormal in all conditions save the never-failing test of fossil remains, and what few occurred left no doubt as to the age of this at first somewhat doubtful rock. *Trigonia alœformis*, *Cardium Hillanum*, *Trochocyathus Harveyanus*, and *Cerithia*, &c., added to the general facies, immediately settled the question of age; neither of the other four borings exhibited any signs of the true Lower Greensand. At Ware and Turnford the Gault rested upon from 8 to 10 inches of the Carr stone, and this was all that represented the Neocomian rocks beyond the 65 feet of chalky oolitic subcalcareous abnormal Lower Greensand; all the borings show that the Neocomian (Lower Greensand) is interrupted on the north by the underground Palæozoic ridge. The geographical extent or surface-area occupied by the Devonian of North Devon between the Pilton beds on the south and the Linton beds on the north (15 miles), where we believe we have the full thickness of the whole series, is as near as possible that known to occur between London and Turnford, assuming that the strike of the North-Devon beds is directly towards the London area, and thence on towards Belgium and the Rhine (Eifel and Coblentz). The Devonian cores brought up at both localities (Tottenham Court Road and Turnford) yielded the same characteristic fossils; and the beds dipped at the same angle at both places, 30° S.E.—the plane of the old land-surface being 1148 feet below London, and 980 feet below Turnford, showing a difference in level of 168 feet, due either to dip or denudation. I should believe the difference was due rather to denudation along or over a given plane striking from S.W. to N.E. Where the junction of the Upper Devonian and Wenlock rocks may take place between Turnford and Ware it is difficult to say; but if we infer that the Ludlow and Lower Devonian beds occur above the Wenlock, dipping south between Ware and Turnford, then there is little room for them, and the Upper Devonian must cease at no great distance north of Turnford. Looking at the thickness of the Lower Devonian in North Devon, and regarding it as maintaining the same in its strike under Wiltshire, Buckinghamshire, Middlesex, and Hertfordshire, there is room in the 8 miles from S. to N. at the dip of 30° S. for the presence of the Lower Devonian and Ludlow. We need not assume that the Ludlow beds do occur, any more than we should expect to find the great sandy and gritty group of the Foreland, whatever it may represent. The old land-surface, therefore, of Devonian and Old Red Sandstone of the southern half of England must have extended from near Yarmouth (lat. N. 52° 30′), descending by a gentle southerly curve to about Leighton Buzzard, thence rising to the Wenlock promontory, and again sharply deflected S.W. to Milford Haven, and on under the Bristol Channel to Cornwall, all east of the Mendip Hills being now covered by the Secondary and Tertiary strata—thus, I think, showing that a widely spread floor of these Palæozoic rocks occurs under the extensive region of the southern half of England, and which could as easily be shown to occur in the north and in Ireland, but under different conditions.

Now that the Ware Upper Silurians have been proved to dip to the south, we may anticipate the occurrence of the more ancient or lower series further north towards Cambridge, Huntingdon, and Peterborough. Whether in their extension northwards they may be of Scandinavian type we can only surmise, unless the Westmoreland and Cumberland Silurians pass under the unconformable and overlapping Carboniferous group of the Penine chain as a continuous floor or old surface to the south.

Since the determination of the existence of the Devonian rocks north of the Thames to Turnford, and of the Upper Silurian at Ware, below the Cretaceous rocks at the depth of 800 feet, our views relative to the distribution of the Coal-measures have materially altered. It is clear that all the stratified rocks between the Silurian and Gault and the Devonian and Gault are wanting or not represented ; in other words, the whole of the Carboniferous, Triassic, and Jurassic rocks, and the Purbecks, &c. are missing north of the Thames to lat. 52° 10′. This shows the great unconformable overlap upon the Silurian and Devonian floor to the west. Had the sub-Wealden boring been completed, the problem as to extension would have been solved. Unfortunately for science this undertaking was never completed, and the problem remained unsolved; the ancient land was not discovered. We must rest content with the hypothesis of Mr. Godwin-Austen as to the area where we should expect to find the Coal-measures, probably ranging, as he suggests, under or north of the North Downs. Life must indeed have been most abundant and prolific in the Wenlock sea of the Ware locality; for so rich in fossils are these Ware beds that no less than 33 species were obtained, all belonging to the Wenlock series, furnishing sufficient data in themselves to establish and determine the age of the rocks in which they occur.

The five borings in the London area, or within the London basin, within a radius of 20 miles, Ware being the furthest removed, taking them in the order in which they were sunk, may be thus enumerated:—No. 1. Kentish Town, 1300 feet deep; the London clay passed through was 350 feet thick, the Reading beds 50 feet, and the Thanet sands 15 feet, Upper Chalk 250 feet, Chalk-marl 30 feet, Upper Greensand 10 feet, Gault 60 feet, and 190 feet of red sandy rock believed to be Old Red Sandstone or a condition of the Devonian; the depth passed through was 1300 feet.

No. 2. The Crossness new well bore-hole about 1030 feet deep. No London clay proper occurred in this sinking; the alluvial clay and gravel immediately below the ordnance level was 20 feet thick, and rested upon the Woolwich and Reading and Thanet beds, here about 100 feet thick, the Chalk 620 feet, the Upper Greensand

33 feet, the Gault 135 feet, succeeded by loose red, coarse, and fine sand, having all the appearance of the New Red Sandstone, and resembling the Kentish-Town Red series.

The boring No. 3, the most important in geological results, was that at Messrs. Meux's, Tottenham Court Road. The London Tertiaries here attained to 156 feet, the Upper Chalk 440 feet, the Lower Chalk and Chalk-marl 215 feet, the Gault and Upper Greensand 190 feet, the Neocomian (of peculiar type) 64 feet; beneath this occurred the Upper Devonian shales at the depth of 1064 feet, with characteristic fossils, *Spirifera disjuncta*, *Edmondia*, *Rhynchonella cuboides*, *Orthis* sp., &c. This was the first indication of the presence of rocks older than the Neocomian east of North Devon and north of the latitude of London, clearly showing the easterly extension of the Palæozoic rocks from the western side of England, and extending towards Holland and Belgium. This boring therefore may be considered classical; it has revealed to us what was surmised intuitively by Mr. Godwin-Austen and Prof. Prestwich. Turnford and Ware have revealed other facts of nearly equal significance, and at the depth of 940 feet and 800 feet.

The 4th boring is that at Turnford, 12 miles north of London, where the London Tertiaries are 100 feet thick, the Chalk 620 feet, the Upper Greensand 15 feet, the Gault 135 feet, the Neocomian, of the Carr-stone type, about 12 inches. We here again prove the position of the dark chocolate-coloured Upper Devonian rocks crowded with characteristic fossils; at the depth of 940 feet I obtained *Spirifera disjuncta*, *Rhynchonella cuboides*, *Rhodocrinus*, *Strophomena rhomboidalis*, *Edmondia*, *Pterinæa*, *Aviculopecten*, *Modiola*, *Avicula damnoniensis*, *A. texturata*, *Fenestella*, *Tentaculites*, &c.

The 5th trial or boring for water was at Ware, east of Hertford, and due north of the Turnford boring. The boring commenced here in the Upper Chalk, which is 416 feet thick, followed by the Chalk-marl 125 feet, the Upper Greensand 77 feet, and the Gault 160 feet, the Neocomian a trace only (8 inches), and of the Carr-stone type, resting upon an eroded surface of Upper Silurian Limestone. The probable relation of these beds to the typical Wenlock series of Wales and Shropshire I have discussed in the earlier portion of this section. No less than 20 species of Brachiopoda alone, with 13 other species, occur and are given in the list; and all were extracted from a core less than 3 feet in length and 1 foot in diameter.

The species collected were the following:—

I. Protozoa: *Ischadites Kœnigii*, Murch. II. Echinodermata: *Periechocrinus moniliformis* and *Taxocrinus* sp. III. Annelida: *Tentaculites ornatus*, Sow. IV. Crustacea: *Phacops caudatus*, Brongn. Mollusca Brachiopoda: *Orthis canaliculata*, Dalm.; *O. elegantula*, Dalm.; *Meristella tumida*, Dalm.; *Cyrtia exporrecta*, Wahl.; *Spirifera elevata*, Dalm.; *S. plicatella*, Linn.; *Athyris* sp.; *Crania implicata*, Sow.; *Rhynchonella cuneata*, Dalm.; *Atrypa reticularis*; *Pentamerus falcatus*, Dalm.; *P. linguifer*, Sow.; *Strophomena euglypha*, Dalm.;

S. reticulata, M'Coy; *S. depressa*, Dalm.; *S. rhomboidalis*, Wahl.; *S. antiquata*, Sow.; *Chonetes* sp.; *Leptæna sericea*, Sow.; *L. transversalis*, Dalm. Conchifera: *Ctenodonta* sp.; *Pterinæa* sp.; *Mytilus mytilimeris*, Conr.; *Orthonota rigida*, Sow. Gasteropoda: *Euomphalus rugosus*, Sow. Cephalopoda: *Orthoceras attenuatum*, Sow.; *O. angulatum*, Wahl.; and *Orthoceras* sp.

These five borings within the metropolitan area are of infinite scientific as well as economic value; and in addition the equally important trials at Burford due west of Ware, and that of Northampton N.W. of London, open up important questions as to the deeply-seated structure of the triangular area having Ware and Burford at its base and Northampton at its apex. Have we within the rolls and folds of the Devonian rocks as they strike across England between latitude 51° and 52° any still undiscovered coal-tracts? is the Bristol coal-field repeated to the east and N.E. to Burford, with the underlying Devonian in place to the south-east? It would appear so when we regard the bearing and strike of the older rocks towards the continent. The geological importance and interest of these borings is their revelation to us of the old Palæozoic land-surfaces, whether coast-lines or tablelands, theoretically enabling us to reconstruct the physiography of those land-masses, concealed, yet connected to now exposed areas, whether British, European, or even American.

February 23, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

William Henry Goss, Esq., Rode Heath, Cheshire, and Stoke-upon-Trent, Staffordshire, was elected a Fellow of the Society.

The following communications were read:—

1. A letter from Dr. John Kirk, communicated to the Society by the Right. Hon. Earl Granville, dated:—

"H.M Agency and Consulate General,
Zanzibar, December 20, 1880.

"My Lord,

"It may be of interest to record the occurrence here of an earthquake-shock felt in the island of Zanzibar at 6.58 a.m., mean time, on the morning of the 18th inst.

"Although the shock was very distinct, no damage appears to have been done to any buildings in town.

"It is now twenty-four years since a similar shock has been here noticed; but on the mainland, especially in the vicinity of Ujiji, they are both more common and more severe than at the coast.

"Shortly after the cable was laid between Mozambique and

Delagoa Bay, the communication was suddenly interrupted after one of these earthquake-shocks, which seems to have caused the falling in of rocks by which the cable was crushed.

"I have the honour to be &c.,
"John Kirk,
H.M. Agent and Consul-General, Zanzibar."

"*The Right Honourable*
Earl Granville, &c. &c.,
London."

2. "The Permian, Triassic, and Liassic Rocks of the Carlisle Basin." By T. V. Holmes, Esq., F.G.S.

3. "On *Astroconia Granti*, a new Lyssakine Hexactinellid from the Silurian Formation of Canada." By Prof. W. J. Sollas, M.A., F.G.S.

The following objects were exhibited :—

Specimens illustrating the transformation of Spodumene into Felspars, from Branchville, Connecticut, exhibited by H. Bauerman, Esq., F.G.S.

Canine of *Deuterosaurus biarmicus*, Eichw., from the Upper Permian of Kargalinsk Steppe, Russia, exhibited by W. H. Twelvetrees, Esq., F.G.S.

Plates prepared for the illustration of the next part of Dr. A. Fritsch's 'Fauna der Gaskohle und der Kalksteine der Permformation Böhmens.'

March 9, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Robert Thompson Burnett, Esq., Irlams o'th'Height, near Manchester; William Erasmus Darwin, Esq., B.A., Basset, Southampton; Charles James Fox, Esq., 26 South Molton Street, W.; and the Rev. T. Granger Hutt, M.A., Sedbergh, Yorkshire, were elected Fellows of the Society.

The following communications were read :—

1. "Description of Parts of the Skeleton of an Anomodont Reptile (*Platypodosaurus robustus*, Ow.).—Part II. The Pelvis." By Prof. Owen, C.B., F.R.S., F.G.S., &c.

2. "On the Order Theriodontia, with a Description of a new Genus and Species (*Ælurosaurus felinus*, Ow.)." By Prof. Owen, C.B., F.R.S., F.G.S.

3. "Additional Observations on the Superficial Geology of British Columbia and adjacent regions." By G. M. Dawson, Esq., D.Sc., F.G.S.

The following specimens were exhibited:—

Skull of *Ælurosaurus felinus*, exhibited by Prof. Owen, in illustration of his paper.

Incisor tooth of *Deuterosaurus biarmicus*, Eichw.; and a Reptilian canine from the Upper Permian Cupriferous Sandstones of Kargalinsk Steppe, near Orenburg, exhibited by W. H. Twelvetrees, Esq., F.G.S.

March 23, 1881.

R. Etheridge, Esq., F.R.S., President, in the Chair.

Rev. Daniel Dutton, Sydney Street, Wellington, New Zealand; and Capt. George Ernest A. Ross, 170 Cromwell Road, S. W., were elected Fellows of the Society.

The following communications were read:—

1. "The Upper Greensands and Chloritic Marl of the Isle of Wight." By C. Parkinson, Esq., F.G.S.

2. "On the Flow of an Ice-sheet, and its connexion with Glacial Phenomena." By Clement Reid, Esq., F.G.S.*

3. "Soil-cap Motion." By R. W. Coppinger, Esq. Communicated by the President.

The following specimens were exhibited:—

A large pebble from the Gault of Folkestone, exhibited by J. S. Gardner, Esq., F.G.S.

Some recent Centipedes, killed near Upata, 60 miles S.E. of Las Tablas, on the Orinoco River, exhibited by G. Attwood, Esq., F.G.S.

April 6, 1881.

J. W. Hulke, Esq., F.R.S., Vice-President, in the Chair.

Edward F. Boyd, Esq., Moor House, Leamside, Fence Houses; Herbert de Haga Haig, Esq., Lieut. R.E., Staff College, Camberley, Farnboro' Station; J. C. Margetson, Esq., 2 Spring Hill, Kingsdown, Bristol; Edward David Price, Esq., Collegiate School, Hounslow; and James Tonge, Esq., Woodbine House, Westhoughton, Bolton-le-Moors, were elected Fellows of the Society.

* This paper has been withdrawn by the author with the permission of the Council.

The following communications were read :—

1. "The Microscopic Characters of the Vitreous Rocks of Montana, U.S." By F. Rutley, Esq., F.G.S. ; with an Appendix by James Eccles, Esq., F.G.S.

2. "On the Microscopic Structure of Devitrified rocks from Beddgelert, Snowdon, and Skomer island." By F. Rutley, Esq., F.G.S.

3. "The Date of the last Change of Level in Lancashire." By T. Mellard Reade, Esq., C.E., F.G.S.

The following specimens were exhibited :—

Specimens of arsenical silver-ore from Gunnison, Colorado, exhibited by H. Bauerman, Esq., F.G.S.

Rocks and rock-sections, exhibited by F. Rutley, Esq., in illustration of his papers.

April 27, 1881.

R. Etheridge, Esq., F.R.S., President, in the Chair.

Samuel Gerrard Kirchhoffer, Esq., M.A., Yately Grange, Farnboro' Station; Arthur Henry Shakespere Lucas, Esq., The Leys, Cambridge; and Frederick Thomas Nelson Spratt, Esq., Lieut. R.E. Clare Lodge, Tunbridge Wells, were elected Fellows of the Society.

The following communications were read :—

1. "On the precise Mode of Accumulation and Derivation of the Moel Tryfan Shelly Deposits ; on the Discovery of similar high-level Deposits along the Eastern Slopes of the Welsh mountains ; and on the Existence of Drift-zones showing probable Variations in the Rate of Submergence." By D. Mackintosh, Esq., F.G.S.

2. "On the Correlation of the Upper Jurassic rocks of England with those of the Continent." By the Rev. J. F. Blake, M.A., F.G.S. Part I. The Paris basin.

3. "On Fossil Chilostomatous Bryozoa from the Yarra-Yarra, Victoria, Australia." By Arthur William Waters, Esq., F.G.S.

The following specimens were exhibited :—

Upper molar of an extinct species of Elephant from the Sivâlic Older Pliocene (?), and Plant-remains in ironstone nodules from Coalbrook Dale, exhibited by E. Charlesworth, Esq., F.G.S.

Specimens from Moel Tryfan and Frondeg gravel-pit, Denbighshire, exhibited by D. Mackintosh, Esq., in illustration of his paper.

May 11, 1881.

R. Etheridge, Esq., F.R.S., President, in the Chair.

Joseph Deeley, Esq., Ruabon, North Wales; George Kilgour, Esq., C.E., F.R.A.S., Dutoit's Pan, Griqualand West, South Africa; and Roderick William MacLeod, Esq., Bengal Staff Corps, 55 Parliament Street, W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "Notes on the Fish-remains of the Bone-bed at Aust, near Bristol, with the Description of some new Genera and Species." By James W. Davis, Esq., F.S.A., F.G.S.

2. "On some Fish-spines from the Coal-measures." By J. W. Davis, Esq., F.S.A., F.G.S.

3. "On some specimens of *Diastopora* and *Stomatopora* from the Wenlock Limestone." By Francis D. Longe, Esq., F.G.S.

[Abstract.]

Mr. Longe showed and described some specimens of Bryozoa from the Wenlock Limestone of Dudley, which he compared with corresponding forms from the Oolites and later periods, and pointed out the close similarity of the Silurian with the later forms, in respect of the shape and dimensions of the cells, as well as in the habit of cœnœcic growth.

Alluding to some other Palæozoic forms, assigned to the Bryozoa under the generic names of *Berenicea* and *Ceramopora*, he pointed out the difference between the shape of the cells in these forms and those which he had described, and expressed a doubt whether they should be classed as Bryozoa at all.

On the other hand, he referred to some specimens described by Professor Nicholson (Ann. & Mag. Nat. Hist. vol. xv. 1875) under the names of *Alecto auloporoides* &c. as having the true Bryozoan cell, and furnishing additional evidence of the existence in the Silurian seas of forms of Bryozoa which, though very abundant in the Oolites and at all subsequent periods, were not generally supposed to have existed in the Palæozoic period.

Discussion.

The President stated that the genus *Aulopora* had never been referred to the Bryozoa before, but to the Actinozoa. He demurred to the use of the term "plant" as applied to the Bryozoa.

The Author stated that the object of his paper was to prove that in the Wenlock beds he had found forms quite undistinguishable from *Stomatopora* or *Alecto*, and *Diastopora* or *Berenicea* of later periods. He had not confounded *Aulopora* with the Bryozoa.

4. "On a new Species of *Plesiosaurus* (*P. Conybeari*) from the Lower Lias of Charmouth, with Observations on *P. megacephalus*, Stutchbury, and *P. brachycephalus*, Owen." By Prof. W. J. Sollas, M.A., F.R.S.E., F.G.S., &c., Professor of Geology in University College, Bristol; accompanied by a Supplement on the Geological Distribution of the Genus *Plesiosaurus*, by G. F. Whidborne, Esq., M.A., F.G.S.

5. "On certain Quartzite and Sandstone Fossiliferous Pebbles in the Drift in Warwickshire, and their probable identity with the true Lower-Silurian Pebbles, with similar fossils, in the Trias at Budleigh Salterton, Devonshire." By the Rev. P. B. Brodie, M.A., F.G.S.

The following specimens were exhibited:—

Fish-spines and Teeth, exhibited by J. W. Davis, Esq., F.G.S., in illustration of his papers; and

Specimens of *Diastopora* and *Stomatopora*, exhibited by F. D. Longe, Esq., F.G.S., in illustration of his paper.

May 25, 1881.

R. Etheridge, Esq., F.R.S., President, in the Chair.

Rev. Tom Bullock Hardern, M.A., LL.M., Burnham Overy, Lynn, Norfolk, was elected a Fellow of the Society.

The following specimens were presented to the Museum:—The type specimens illustrating the "Note on the 'Tubulations Sableuses' of the 'Étage Bruxellien' in the Environs of Brussels" by H. J. Carter, Esq., F.R.S. (Ann. & Mag. Nat. Hist. May 1877), who presented them.

The following communications were read:—

1. "On the Discovery of some Remains of Plants at the base of the Denbighshire Grits, near Corwen, North Wales." By Henry Hicks, M.D., F.G.S. With an Appendix by R. Etheridge, Esq., F.R.S., Pres. Geol. Soc.

2. "Notes on a Mammalian Jaw from the Purbeck Beds at Swanage, Dorset." By Edgar W. Willett, Esq. Communicated by the President.

The following specimens were exhibited:—

Specimens of the Reptile Fauna of the Gosau Formation, exhibited by Prof. H. G. Seeley, F.R.S., F.G.S.; and

Specimens exhibited by Messrs. Hicks and Willett in illustration of their papers.

June 8, 1881.

R. Etheridge, Esq., F.R.S., President, in the Chair.

The Meeting was made a Special General Meeting for the election of a Member of the Council in the room of the late Sir P. de Malpas Grey-Egerton, Bart., M.P., F.R.S., F.G.S.

The President announced that the late Sir Philip Egerton had bequeathed to the Society all the original drawings made from specimens in the collection of the Earl of Enniskillen for the illustration of Prof. Agassiz's works on Fossil Fishes. The Society had long possessed the drawings made for the same purpose from the Earl of Ellesmere's collection, and some years ago the Earl of Enniskillen presented those which had been prepared from specimens in the possession of Sir Philip Egerton. Sir Philip Egerton's kind bequest would complete this interesting series.

Mr. John Evans remarked that on this, as on so many other occasions, the Society was deeply indebted to the kindness of the late Sir Philip Egerton, and proposed that the President and Secretaries should be instructed to communicate with Sir Philip's representatives, and to express the gratitude of the Society for this bequest and their condolence with his relatives on the loss they have sustained.

Prof. W. Boyd Dawkins seconded this proposal, which was carried unanimously.

The ballot for a new member of Council was kept open till 9 o'clock, when Sir John Lubbock, Bart., M.P., F.R.S., was declared to have been elected.

Grenville A. J. Cole, Esq., Mayland, Sutton, Surrey, and J. L. Roberti, Esq., 92 Malpas Road, New Cross, S.E., were elected Fellows; and Il Commendatore Quintino Sella, of Rome, a Foreign Member of the Society.

The following names of Fellows of the Society were read out for the first time in conformity with the Bye-laws, Sect. VI. b, Art. 6, in consequence of the non-payment of the arrears of their contributions:—J. Entwisle, Esq.; R. Koma, Esq.; W. H. Le Feuvre, Esq.; C. S. Mann, Esq.; Joseph Thompson, Esq.

The following communications were read:—

1. "The Reptile-Fauna of the Gosau Formation, preserved in the Geological Museum of the University of Vienna." By Prof. H. G. Seeley, F.R.S., F.L.S., F.G.S.; with a Note on the Geological Horizon of the Fossils, by Prof. Edward Suess, F.M.G.S.

2. "On the Basement-beds of the Cambrian in Anglesey." By Prof. T. McKenny Hughes, M.A., F.G.S.

3. "Description and Correlation of the Bournemouth Beds.—Part II. Lower or Freshwater Series." By J. S. Gardner, Esq., F.G.S.

Specimens were exhibited by Messrs. Seeley, Hughes, and Gardner, in illustration of their papers.

June 22, 1881.

R. Etheridge, Esq., F.R.S., President, in the Chair.

Thomas Hart, Esq., Richmond Terrace, Blackburn; and David William Jones, Esq., Coronel, Chili, South America, were elected Fellows of the Society.

Specimens of Tertiary Brachiopods from South Australia, and three specimens of Mesozoic Belemnites from Central Australia, were presented to the Museum by Prof. R. Tate, F.G.S.

The following names of Fellows of the Society were read out for the second time in conformity with the Bye-laws, Sect. VI. b, Art. 6, in consequence of the non-payment of the arrears of their contributions:—J. Entwisle, Esq.; R. Koma, Esq.; W. H. Le Feuvre, Esq.; C. S. Mann, Esq.; Joseph Thompson, Esq.

The following communications were read:—

1. "Description of a new Species of Coral from the Middle Lias of Oxfordshire." By R. F. Tomes, Esq., F.G.S.

2. "Note on the Occurrence of the Remains of a Cetacean in the Lower Oligocene Strata of the Hampshire Basin." By Prof. J. W. Judd, F.R.S., Sec. G.S. With a Note by Prof. H. G. Seeley, F.R.S., F.G.S.

3. "Description of a Peat-bed interstratified with the Boulder-drift at Oldham." By G. H. Hollingworth, Esq., F.G.S.

4. "Silurian Uniserial *Stomatoporæ* and *Ascodictya*." By G. R. Vine, Esq. Communicated by Prof. P. Martin Duncan, F.R.S., F.G.S.

5. "Note on the Diamond-fields of South Africa." By. E. J. Dunn, Esq. Communicated by Prof. Ramsay, F.R.S., F.G.S.

6. "On a new *Comatula* from the Kelloway Rock." By P. H. Carpenter, Esq., M.A., Assistant Master at Eton College. Communicated by the President.

7. "Descriptive Catalogue of Ammonites from the Sherborne District." By Sydney S. Buckman, Esq. Communicated by Prof. J. Buckman, F.G.S., F.L.S., &c.

The following specimens were exhibited :—

Prehistoric remains (pottery &c.) found by J. B. Andrews, Esq., of Mentone, at St. Vallier, near Grasse, in the neighbourhood of dolmens &c.

Specimens exhibited by Messrs. Tomes and Judd in illustration of their papers.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

Session 1880–81.

I. ADDITIONS TO THE LIBRARY.

1. Periodicals and Publications of Learned Societies.

Presented by the respective Societies and Editors, if not otherwise stated.

Academy, The. Nos. 425–451. 1880.
The British Association at Swansea, 157, 176, 190.

——. Nos. 452–478. 1881.

Adelaide. Philosophical Society. Transactions and Proceedings and Report for 1878–79. 1879.
R. Tate. Anniversary Address, xxxix.—G. Scoular. The Geology of the Hundred of Munno Para, Part 1, 60.—O. Tepper. Introduction to the Cliffs and Rocks at Androssan, Yorke's Peninsula, 71.—R. Tate. The Natural History of the Country around the Head of the Great Australian Bight, 94.—R. Tate. Zoologica et Palæontologica Miscellanea, chiefly relating to South Australia, 129.

——. Royal Society of South Australia. Transactions and Proceedings and Report. Vol. iii., for 1879–80. 1880.
R. Tate. Anniversary Address, 39.—J. E. Tenison-Woods. On some recent and fossil Australian Selenariadæ, 1.—Otto Tepper. The "Bay of Biscay" Soil of South Australia and its Formation, 91.—J. E. Tenison-Woods. On some new Corals from the Australian Tertiaries, 99.—R. Tate. Description of a new Species of Belemnite from the Mesozoic Strata of Central Australia, 104.—G. Scoular. The Geology of the Hundred of Munno Para, Part 2, 106.—R. Tate. On the Australian Tertiary Palliobranchs, 140.—R. Tate. Rock-formations and Minerals in the vicinity of Peake, C. A., 179.—W. Fowler. Sections of Strata traversed by two wells at Yarrow, in the Hundred of Clinton, 181.

Albany. New-York State Museum of Natural History. Annual Reports, Nos. 28 (Museum edition, 1879), 29–31. 1878–79. *Presented by James Hall, Esq., F.M.G.S.*

Analyst, The. Vol. v. Nos. 52–57. 1880.

——. Vol. vi. Nos. 58–63. 1881.

Annals and Magazine of Natural History. Ser. 5. Vol. vi. Nos. 31–36. 1880. *Purchased.*
C. Lapworth. On the Geological Distribution of the Rhabdophora, 16.—A. W. Waters. Note on the Genus *Heteropora*, 156.—C. Lapworth. On the Geological Distribution of the Rhabdophora, 185.—H. J. Carter.

On fossil Sponge-spicules from the Carboniferous Strata of Ben Bulben, near Sligo, 209.—G. Cotteau. On the Tertiary Echinida of Belgium, 246.—R. Etheridge, Jun. Notes on the Gasteropoda contained in the Gilbertson Collection, British Museum, and figured in Phillips's 'Geology of Yorkshire,' 289.—A. J. Jukes-Brown. The Chalk Bluffs of Trimmingham, 305.—H. Alleyne Nicholson. On the Minute Structure of the recent *Heteropora neozelanica*, Busk, and on the Relations of the Genus *Heteropora* to *Monticulipora*, 329, 414.—A. Agassiz. On Palæontological and Embryological Development, 348.—J. W. Davis. On a Species of *Gyracanthus*, a fossil Fish from the Coal-measures, 372.—W. J. Sollas. On the Flint Nodules of the Trimmingham Chalk, 384, 437.

Annals and Magazine of Natural History. Ser. 5. Vol. vii. Nos. 37–42. 1881. *Purchased.*

H. A. Nicholson. On some new or imperfectly-known Species of Corals from the Devonian Rocks of France, 14.—R. Etheridge, Jun. Descriptions of certain peculiar Bodies which may be the Opercula of small Gasteropoda, discovered by Mr. James Bennie in the Carboniferous Limestone of Law Quarry near Dalry, Ayrshire, with Notes on some Silurian Opercula, 25.—W. J Sollas. Note on the Occurrence of Sponge-spicules in Chert from the Carboniferous Limestone of Ireland, 141.—G. C. Wallich. On the Origin and Formation of the Flints of the Upper or White Chalk; with Observations upon Prof. Sollas's Paper in 'The Annals and Magazine of Natural History' for December 1880, 162.—S. H. Scudder. Relation of Devonian Insects to Later and Existing Types, 255.—G. C. Wallich. On Siliceous Sponge-growth in the Cretaceous Ocean, 261.—P. H. Carpenter and R. Etheridge, Jun. Contributions to the Study of the BritishPalæozoic Crinoids, 281.—H. J. Carter. On the Kunker Formation of the Alluvium in India compared with the Flint Formation in the Chalk of England, 308.—H. Filhol. The Bears of the Cavern of Lherm, 428.—J. W. Davis. On *Palæospinax priscus*, Egerton, 429.—S. H. Scudder. The Structure and Affinities of *Euphoberea*, Meek and Worthen, a Genus of Carboniferous Myriopoda, 437.—O. C. Marsh. Discovery of a fossil Bird in the Jurassic of Wyoming, 488.

Athenæum (Journal). Nos. 2748–2774. 1880.

A. C. Ramsay. Address delivered at the Swansea Meeting of the British Association for the Advancement of Science, August 25, 1880, 263. —British Association at Swansea, 309.

——. Nos. 2775–2799. 1881.

Sir Philip de Malpas Grey Egerton, Bart., M.P., 494.—The Hamád, 817.

——. Parts 630–636. 1880.

——. Parts 637–640. 1881.

Barnsley. Midland Institute of Mining, Civil, and Mechanical Engineers. Transactions. Vol. vii. Part 50. 1880.

T. W. Embleton. On an Outburst of Carbonic Acid Gas in the Rochebelle Coal Mine, France, 89.

——. ——. ——. Vol. vii. Parts 52 and 53. 1881.

Basel. Schweizerische paläontologische Gesellschaft. Abhandlungen. Vol. vii. 1880. *Purchased.*

Forsyth Major. Beiträge zur Geschichte der fossilen Pferde.—Ph. de la Harpe. Etude des Nummulites de la Suisse et révision des espèces éocènes des genres *Nummulites* et *Assilina.*—L. Rütimeyer. Beiträge zu einer natürlichen Geschichte der Hirsche.—F. Koby. Monographie des polypiers jurassiques de la Suisse.—P. de Loriol. Monographie paléontologique des couches de la zone à *Ammonites tenuilobatus* (Badener Schichten) d'Oberbuchsitten et de Wangen (Soleure).—P. de Loriol. Description de quatre échinodermes nouveaux.

Belfast Natural-History and Philosophical Society. Proceedings for the Sessions 1878–79, 1879–80. 1880.

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