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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EXPLANATION OF THE PLATES.

ERRATA ET CORRIGENDA.

Page 79, line 24, *for* flints becoming *read* flints elsewhere becoming.
,, 348, note, *for* menalite *read* melanite.
Plate XX. fig. 2, the lines from the letters "ng" should run to the smooth instead of to the broken surfaces.

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1. *On* Concretionary Patches *and* Fragments *of* other Rocks *contained in* Granite*. By J. Arthur Phillips, Esq., F.G.S. (Read November 19, 1879.)

[Plate I.]

No one who is in the habit of visiting granite-quarries, or who has had frequent opportunities of examining granite, either in a dressed or in a polished state, can have failed to observe that it frequently contains patches which resemble imbedded fragments of older rock. These patches or nests are usually, although not always, darker in colour than the granites in which they occur, while their form may be either rounded or more or less angular. In the first case the patch resembles an enclosed pebble, while in the second it often presents the appearance of a fragment of slate or mica-schist. Such patches most frequently have their outlines clearly and sharply defined, but they occasionally merge by almost insensible gradations into the enclosing granite.

They are usually finer in grain than the granites in which they are found, and, from being less easily attacked by atmospheric agencies, not uncommonly stand out in considerable relief from the surfaces of weather-worn boulders. The union of the enclosed patch with the enclosing rock is generally complete, and their

* In this paper fine-grained granitic patches or nodules, although not exhibiting a concentric structure, are spoken of as concretionary. They are also sometimes mentioned as concretions.

cohesion is so perfect that it is seldom difficult to obtain hand specimens exhibiting the line of junction of the two.

Such bodies sometimes enclose crystals of felspar similar in all respects to those of the enclosing granite, excepting that in the majority of cases their angles are more distinctly rounded; patches of this kind occasionally contain others either of a lighter or of a darker colour than themselves. The inclusions in granitic rocks, although they have long attracted the attention of geologists, do not appear to have been often a subject of investigation; they have, however, been mentioned by various authors, who have accounted for their presence in different ways.

In his ‘Geological Classification of Rocks’ (p. 230), published in 1821, Dr. John Macculloch writes as follows:—

“The magnitude of the parts in granite is extremely various, each constituent mineral sometimes exceeding an inch in dimensions, and at others being almost invisibly minute. Various textures are also often united in a very limited space, or the rock passes imperceptibly from fine- to coarse-grained. Occasionally also irregular patches or veins, of a fine texture, are seen imbedded in a coarser variety. In one rare instance the parts affect a spheroidal arrangement.”

Naumann (1858) observes :—“Pseudofragmentary Concretions. These appear like more or less sharp-angled fragments, but without being so. Such concretions occur not unfrequently in granite and syenite and in other rocks made up of crystalline silicates; they have sometimes been quite erroneously interpreted, having been really taken for what they seem to be” *.

The same author subsequently remarks:—“In this connexion we have yet another opinion to consider, to which attention has already been called (i. p. 919), the opinion, namely, that these fragments are not really to be regarded as such, but merely as fragment-like concretions. That concretions really sometimes occur which in their form possess a deceptive resemblance to angular or rounded fragments is certainly no more to be denied than that occasionally fragments acquire the appearance of concretions (i. pp. 422 and 560) by the fusion and rounding of the contours” †.

Hochstetter states that the island of Billiton is, like Banca, principally granite, and that the rocks closely resemble the stanniferous granites of the Carlsbad district, including a porphyritic granite like that of the neighbourhood of Marienbad, containing the same highly micaceous fine-grained dark enclosures of globular form ‡.

Under the heading of “Segregation of Granites,” Jokély makes the following observations :—“Besides the lamellar, spherical, concentrically-coated, and more irregular segregations also make their appearance. The spherical is usually combined with the scaled, whilst the spheroidal or ellipsoidal forms which are met with in

* C. F. Naumann, Lehrb. der Geognesie, 2. Auf. vol. i. p. 422.

† *Ibid.* vol. ii. p. 203.

‡ F. Hochstetter, Jahrb. k.-k. geol. Reichsanstalt, 1858, p. 285.

many places are usually only the interior, harder nuclei of former larger blocks of concentric structure, which remain behind as such after their outer bark, as it were, has peeled off. Within such round blocks there is frequently an inner concretion, from $\frac{1}{2}$ to 2 feet and more in diameter, which consists essentially of aggregations of mica, and probably may in most cases have been the first inducement to the concentric scaled structure. Locally these concretionary enclosures are called 'souls.' This segregation occurs in most varieties of granite, but especially in the finer-grained ones" *.

A still more recent writer on the geology of Bohemia makes the following observations on the granites of that country:—"One of the most remarkable peculiarities of this variety of granite (hornblende granite) is the innumerable fine-grained enclosures which it contains. They are always sharply segregated from the containing rock, and are of all sizes, from that of the fist to that of a pin's head. The ground-mass of these fragments is of a dark colour, consisting of mica and small quartz-grains, in which white orthoclase crystals are for the most part porphyritically developed. The enclosures also contain hornblende crystals, although not in such quantity as in the enclosing rock. It is difficult to say any thing as to the mode of production of these fragments; but from the identity of the constituents and from their great abundance, it would appear that they were not derived from a rock broken through, but the product, during the solidification of the whole mass, of a process of segregation, the nature of which is entirely unknown to us. The circumstance must be noted, however, that they are exclusively confined to the area of the hornblende granite, but entirely absent in the other varieties"†.

A very remarkable example of concretionary granite is described in the U. S. Report on the Geology of Vermont ‡. "The basis of this remarkable variety of granite is rather fine-grained, white and highly felspathic. The mica, however, is usually dark, and where it exists in large quantities it gives the rock the aspect of syenite. But there is no hornblende present. Scattered through this base occur numerous spheroidal or elongated and somewhat flattened nodules of black mica, from half an inch to two inches in diameter; and when elongated the longer axis is sometimes seen as much as four or five inches long. They are usually more or less flattened, and have a shrivelled appearance like dried fruit. They sometimes become so thin as to consist only of a few plates........When the nodule is elongated and the wrinkles correspond, as they always do, to the longer axis, the resemblance is very striking to a dried

* Johann Jokély, "Geogn. Verhältnisse in einem Theile des mittleren Böhmen," Jahrb. k.-k. geol. Reichsanstalt, 1855, p. 375.

† F. von Andrian, "Beiträge zur Geologie des Kauřimer und Taborer Kreises in Böhmen," *ibid.* 1863, p. 166.

‡ Report on the Geology of Vermont, by Edward Hitchcock, LL.D., Edward Hitchcock, Jun., M.D., Albert Hager, A.M., and Chas. H. Hitchcock, A.M., vol. ii. p. 564, 1861.

butternut, more especially when stripped of its epicarp. No wonder they should be called 'petrified butternuts'...... If a specimen, somewhat flattened, be placed on its edge, and a moderately sharp blow be given to it with a hammer, concavo-convex scales will be chipped off even to the centre. They are composed of layers of mica with granular quartz, and probably some felspar interposed. The structure is evidently concretionary; yet, as already intimated, one can hardly avoid the suspicion that something has been abstracted from some of them, causing a shrinkage."

At page 721 of the same volume, the Rev. S. Hall remarks:—"These singular nodules seem to be imbedded in the granite mass 'like plums in a pudding.' They extend only a short distance from the place where first found in Stanstead. From that place to Craftsbury the granite exhibits no unusual appearance. At the south village in the latter town is an immense bed of nodular granite, some of which seems to be composed almost entirely of nodules slightly cemented by grains of mica and quartz. Other parts of the rock are very solid, and not inclined to decomposition more than other granite."

In a paper "On the Metamorphic Origin of certain Granitoid Rocks and Granites in the Southern Uplands of Scotland" *, Mr. J. Geikie, F.R.S., describes "nests" of altered rock which occur in some of the grey granites of that district. These, he says, often exhibit distinct traces of lamination; and their most usual character is that of an exceedingly fine-grained mica-schist, the dark or almost black shade being due to the abundance of mica. They are very irregular in shape, and by no means confined to those portions of the rock which abut upon the outlying bedded or aqueous strata, but are, on the contrary, scattered indiscriminately throughout the granite. He subsequently proceeds to account for the presence of these nests, and states that they "either represent such little detached portions of shale as are of common occurrence in the Lower Silurian greywackés, or they may be remnants of thin bands or beds of shale that interleaved the original strata. Those who deny the metamorphic origin of granite will probably suggest that the 'nests' of altered rock may have been caught up by the granite during its progress through the strata that envelope it. But if this had been the case, we should certainly expect to find the 'nests' not only more abundant near the junction of the granite with the stratified rocks, but indeed almost, if not exclusively, confined to that area. They are not more characteristic, however, of one portion of the granite than of another, but, as already remarked, are scattered indiscriminately throughout. I am therefore forced to conclude that the crystalline rocks described above have resulted from the alteration *in situ* of certain bedded deposits. The occurrence of the 'nests' cannot be accounted for on any other theory."

None of the published descriptions of these concretions or enclosures in granites appear to have resulted from investigations founded either upon chemical analysis or upon a microscopical examination

* Geol. Mag. vol. iii. p. 533.

of thin sections; and I have consequently been induced to avail myself to some extent of those methods of research in the hope of being thereby enabled to more clearly determine than has hitherto been done the nature and origin of such bodies. In carrying out this work, I first examined some of the principal quarries in the granite districts of the west of England, and subsequently those in the neighbourhood of Shap, in Westmoreland. I afterwards made myself acquainted with those in the vicinity of Aberdeen and Peterhead in Scotland, and examined numerous specimens from the district about Fort William collected by Mr. C. W. Merrifield, F.R.S.; finally the granite-quarries situated in the vicinity of Newry and Castlewellan in Ireland were visited.

In the following pages I propose to describe the various granites and their respective inclusions in the order in which the several districts were examined, beginning with a quarry at Lamorna Cove in West Cornwall, five miles south-west from the town of Penzance.

English Granites.—The granite-quarries at Lamorna are situated mainly in the cliff forming the more easterly shore of Lamorna Cove, and they have, at various times, been somewhat extensively worked for building-material. The granite from this locality is grey in colour and moderately coarse in structure, occasionally enclosing crystals of white felspar an inch and a half in length, together with numerous smaller ones possessing a distinctly greenish shade. Crystalline granules of a brownish transparent quartz are also abundant, as is likewise a nearly black mica, which is disseminated in minute scales throughout the other constituents. Black patches are exceedingly abundant in this granite, and have generally the appearance of fine-grained enclosures with irregular outlines; not unfrequently these exhibit a texture closely resembling that of a hardened slate or micaceous schist, and they are sometimes observed to be traversed by strings or veins of the enclosing granite. The frequency of the occurrence of black patches in this rock considerably detracts from its value as a building-material, as may be seen in the Museum building at Penzance, the front of which is constructed of Lamorna granite containing numerous dark spots. In this quarry the dark patches sometimes include imperfect crystals of quartz of considerable size, resembling in all respects those of the surrounding granite.

When examined under the microscope the mica of this granite appears to be chiefly of a dark brown colour, and is observed to be marked by circular, or nearly circular, spots of a much darker shade; in the centre of many of these markings a crystal of apatite occurs as a nucleus. This mica is often penetrated by well-formed crystals of unaltered magnetite, which is also found, although with less frequency, in the crystals of felspar and quartz. The presence of white mica is somewhat exceptional; but this granite contains light-brown tourmaline as well as a few small crystals of apatite.

The quartz of this rock encloses the usual liquid-cavities, which, however, are not generally numerous; the felspar is in part orthoclase, but a notable proportion of a plagioclastic species is also present. The crystals of orthoclase often enclose grains of quartz and patches of a triclinic felspar.

Six different sections were prepared of as many dark micaceous inclusions from this locality, and, with the exception of two, they were found, when examined under the microscope, to differ from one another in the fineness of their grain only. Four of the specimens consist essentially of a mixture of granular quartz with felspar, through which numerous flakes of dark mica are disseminated.

The felspar does not very often exhibit any traces of triclinic striation; but the plates of mica are usually arranged with their axes approximately parallel to the same plane. As is almost invariably the case in this locality, the inclusions are much closer in grain than the granite, and the quartz, which is found chiefly in patches, occurs mostly in granules from ·75 millim. to 1 millim. in diameter. In addition to the foregoing constituents, these patches enclose minute and imperfectly crystallized garnets of a dark-green colour, magnetite, or ilmenite, and imperfect crystals of tourmaline. The larger crystals of garnet are sometimes ·5 millim. in diameter, while the smaller ones are frequently made up of an aggregation of exceedingly minute blebs separated from one another by spaces filled up with quartz.

The two remaining sections of inclusions from this locality differ from the preceding only in containing a less proportion of felspar, the absence of which is compensated for by the presence of a large quantity of a bacillar colourless mineral, which is probably tremolite.

At Wicca Pool, Zennor, granite in the form of veins penetrates for a considerable distance into the mica-slates forming the sea-cliff, and fragments of slate which have been detached from the general mass have become enclosed in the granite. These enclosed fragments are angular, their outlines are sharply defined, and their union with the surrounding granite along the surfaces of contact is complete.

In general appearance the included fragments can scarcely be distinguished from specimens of the general mass of the micaceous rock taken from along the line of its direct contact with the intrusive granite, excepting that foliation has been almost obliterated. Sections of the mica-slate in contact with the granite are seen under the microscope to consist of a mixture of granular quartz, brown mica, and a little white mica—the last being present in very small quantity only, with a few occasional minute garnets and a considerable amount of magnetite in the form of disseminated grains.

Thin sections prepared from fragments found by Mr. H. Bauerman enclosed within the granite do not differ materially from those made from contact specimens, excepting that both the quartz and mica are in this case more distinctly crystalline.

When seen in polarized light, sections cut from the included fragments and those from the slate in immediate contact with the granite veins are scarcely to be distinguished from one another, as the grains of quartz in the contact-specimens then become well defined; their average diameter, from ·07 millim. to ·1 millim., is the same in both instances.

The grey granite extensively quarried in the neighbourhood of Penryn is almost entirely free from patches differing materially, either in texture or colour, from the surrounding rock. Such bodies are, however, to some extent, represented by occasional aggregations of a few large flakes of mica. One of these nests, of about the size and thickness of a shilling, from Carnsew quarry was found to consist of a mixture of greyish-white and black micas without any admixture either of quartz or felspar.

The granites in the neighbourhood of St. Austell, the majority of which are to a greater or less extent schorlaceous, and which are sometimes marked by reddish-brown spots resulting from the peroxidation of ferrous compounds, are generally free from nests differing in texture or colour from the surrounding rock; and although several quarries in this district were examined, no specimens of inclusions were obtained.

At Gready, in the parish of Luxulyan, a large quarry has been opened upon a coarse-grained grey granite containing a moderate amount of black and silvery-white mica, with occasional crystals of schorl. This granite sometimes contains spheroidal or ovoid bodies very dark in colour, and closely resembling water-worn pebbles of fine-grained "greenstone"; these are firmly imbedded in the rock and exhibit distinct and sharply defined outlines.

An inclusion from the Gready quarry, one half natural size, is represented in fig. 1, Pl. I.

An examination of thin sections of the coarse-grained granite from this locality does not afford much information which might not be obtained by a careful study of hand specimens with the aid of a lens.

The black and silvery-white micas are, however, seen to be often interlaminated, while the former frequently encloses a considerable amount of magnetite with occasional minute crystals of apatite. The dark mica in this rock is affected by the deeper brown spots previously referred to as occurring in the micas of other Cornish granites, and the quartz contains the usual liquid-cavities. A notable proportion of the felspar is triclinic, and the rock contains a few small garnets.

Sections cut from rounded pebble-like patches found in this quarry, when examined under the microscope, are found to be, with perhaps the exception of schorl, composed of the same minerals as the enclosing granite; but the crystals are much smaller and the proportion of black mica is larger. A large portion of the felspar has been rendered cloudy by an opaque product of alteration; but wherever the crystals have retained their original transparency a preponderance of triclinic felspar becomes apparent. An alteration-product of a greenish shade is also present.

The following analysis of a specimen of granite from Gready quarry has, for convenience of comparison, been placed side by side with one of a close-grained dark-coloured ovoid inclusion from the same locality. The granite selected for analysis was that immediately surrounding the inclusion of which the composition is given.

		Granite.	Inclusion.
Water	hygrometric	·13	·18
	combined	·59	1·25
Silica		69·64	65·01
Phosphoric anhydride		trace	trace
Alumina		17·35	17·37
Ferric oxide		1·04	4·95
Ferrous ,,		1·97	1·86
Manganous oxide		trace	trace
Lime		1·40	2·11
Magnesia		·21	1·34
Potassa		4·08	1·82
Lithia		trace	trace
Soda		3·51	4·14
		99·92	100·03
Specific gravity		2·72	2·73

The results of chemical analysis are thus perfectly in accordance with those which might have been anticipated from a microscopic examination of the two rocks. A considerable proportion of the orthoclase in the granite is, in the inclusion, represented by a soda-lime felspar, probably oligoclase, while the marked increase in the quantities of ferric oxide and magnesia in the latter are doubtless chiefly referable to an augmentation in the proportion of mica present *.

The granite of the Cheesewring quarries, near Liskeard, is without inclusions, but is traversed by veins of fine-grained granite, containing a pinkish biaxial mica (lepidolite), in which triclinic felspar is abundant.

At Gunnislake the granite does not contain any patches presenting definite and distinct ontlines; but wherever spots occur they gradually merge into the normal rock. Sections prepared from these indistinct aggregations are found to consist of a fine-grained granite, in which triclinic felspar is perhaps somewhat more abundant than in the surrounding rock.

The only granite which I have examined from the county of Devon is that raised at the extensive quarries of Foggen Tor, near the great prison of Prince's Town on Dartmoor. This is a grey granite, generally without pebble-like inclusions bounded by distinct and well-defined outlines. A few patches of fine-grained granite, considerably darker in colour than the surrounding rock, were, however, found. The outlines of these are moderately sharp, and, in one instance, a patch of this description encloses a crystal of orthoclase, the angles of which are rounded, as well as two distinct crystals of quartz, similarly modified. Fig. 2, Pl. I., represents this specimen, natural size.

* The Rev. S. Haughton, F.R.S., states that the second felspar in Cornish granites is albite (Proc. Roy. Soc. vol. xvii. p. 209). There are, however, probably exceptions to this; and, in the present instance, the results of analysis render the presence of orthoclase probable.

When thin sections of Foggen-Tor granite are examined under the microscope, they are all seen to consist of orthoclase, quartz, dark-brown mica, schorl, and a little silvery-grey mica; a plagioclastic felspar is also present; but no magnetite was observed. It may, however, be remarked that this rock, like some of the granites in the neighbourhood of St. Austell, is occasionally marked by reddish-brown spots, apparently resulting from the oxidation of some mineral containing ferrous oxide.

A section of the fine-grained patch enclosing crystals of quartz and a rounded crystal of orthoclase, when examined under the microscope, is seen to be composed of the same minerals as the surrounding rock, the only difference being in the dimensions of the component crystals and the presence of a larger proportion of nearly black mica.

This is, therefore, simply a nest of darker-coloured granite, and is probably a concretionary product, although it has been ascertained, by cutting through the specimen, that the large rounded crystal of orthoclase does not extend beyond the darker fine-grained patch into the normal granite. This granite sometimes contains large druses or "vughs" lined with quartz crystals, while it occasionally becomes decomposed into a soft kaolin, in which dissociated silica is imbedded in the form of aggregated crystals of nearly transparent quartz.

The well-known granite of Shap in Westmoreland, which is remarkable for its beautiful crystals of pinkish-red orthoclase, and is extensively wrought for ornamental purposes, encloses numerous rounded patches of a darker colour than the surrounding rock, which, at first sight, present the appearance of fine-grained inclusions of trap. This granite, in hand specimens, is seen to consist of a ground-mass of quartz, felspar, and black mica, porphyritically enclosing large crystals of red orthoclase; but, when examined under the microscope, it is found to contain, in addition to those minerals, magnetite, titanite, a little apatite, hornblende, and occasionally some triclinic felspar.

The patches in this granite are well defined, and generally more or less rounded in outline, varying in size from that of a pea to that of a water-melon. They are commonly much finer in grain than the surrounding rock; and, on account of the presence of a larger proportion of black mica, are, in a great majority of cases, considerably darker in colour. In some instances a portion of the mica included in these dark patches would appear to have become segregated from the surrounding granite, which, in the immediate neighbourhood of the inclusion, is comparatively free from the presence of that mineral.

The rounded pebble-like bodies which occur in this granite frequently enclose crystals of the beautiful red orthoclase characteristic of the surrounding rock; but these are generally imperfect in form and have their angles considerably rounded.

Fig. 3, Pl. I., represents a sharply defined inclusion in the Shap granite, scale four-tenths natural size, which, in addition to numerous small patches of red orthoclase, contains a large crystal of that mineral, the angles of which are rounded.

A large dark-coloured fine-grained patch observed in this rock contains a smaller one considerably lighter in colour and presenting very distinct outlines. Besides imperfect and much-rounded crystals of red and white felspar, this specimen encloses a large milky felspar crystal of which the angles are perfectly sharp.

Six sections were examined, from as many rounded enclosures, from the Shap quarries, and, without exception, the ground-mass of the whole of them was found to contain all the various minerals constituting the normal granite of the district, although the proportion of dark mica present was in considerable excess. Triclinic felspar appears to be more abundant in the inclusions than in the surrounding granite, and a portion of this mineral shows cross striation in polarized light; a few of the crystals exhibit concentric lines of growth.

In exceptional cases the patches in Shap granite, from the almost total absence of black mica, are lighter in colour than the surrounding rock; and occasionally two distinct inclusions, differing both in texture and colour, are found one within the other.

In addition to the rounded masses already described, this granite encloses others of a more schistose character, which are often softer than the rock in which they are contained. Sections of inclusions of this kind are seen under the microscope to consist either entirely of mica, or of mica associated with quartz and occasional crystals of felspar. When composed of mica alone, these inclusions can scarcely be regarded otherwise than as being of segregationary origin; but where quartz in considerable quantity is also present a fragment of mica-schist may sometimes have become enclosed in the granite.

The method of occurrence of such bodies in Shap granite will be understood by reference to Pl. I. figs. 4, 5, natural size, carefully drawn by Mr. Frank Rutley. Whether these be the result of included flakes of a stratified rock, or of the segregation of mica only, it is evident that they must have been at least partially consolidated previous to the crystallization of the felspar. It will be observed that in fig. 4 the inclusion is completely divided by a large crystal of orthoclase, while in fig. 5 a crystal of that mineral is traversed by fragmentary portions of a similar body. It is somewhat unfortunate that, as the drawings were made from a polished pillar, it was impossible to obtain thin sections of these particular inclusions.

Scotch Granites.—The Scotch granites of which I have examined the inclusions are those in the neighbourhood of Aberdeen, Peterhead, and Fort William.

The Aberdeen granites are grey in colour and fine in grain, and are mainly composed of quartz and felspar, with colourless and dark or nearly black micas. The granite of this district is regarded by Prof. Haughton as being of metamorphic origin*, and is apparently almost free from rounded or pebble-like inclusions.

* Proc. Roy. Soc. vol. xviii. p. 313.

When thin sections are examined under the microscope they are found to be composed, in addition to orthoclase and quartz, of a large proportion of a triclinic felspar, which Profs. Haughton and Heddle have determined to be oligoclase *; this granite also contains a colourless and a nearly black mica, a few minute garnets, and occasionally crystals of apatite and sphene †. A portion of the felspar exhibits cross hatching in polarized light, and the quartz is frequently traversed by hair-like crystals, which are probably either schorl or rutile.

A subangular inclusion obtained from Rubislaw quarry, two miles west of Aberdeen, is about 5 inches in length, and resembles a contorted fragment of mica-schist. Sections of this specimen are seen to be composed of quartz and felspar, with dark and colourless micas. A considerable proportion of the felspar is triclinic, and the cleavage-planes of the micas are parallel to the foliation of the rock. One or two small garnets were also observed. Other inclusions from this locality, of nearly similar appearance, but of smaller dimensions, were collected, and on examination were found to have the same composition.

At Sclattie quarry, near Buxburn, I found a large piece of silvery grey schistose rock, weighing several pounds, enclosed in granite. Its surfaces, which were in no way altered, were most completely united with the granite, which was itself quite unaltered in the immediate proximity of the enclosure; the line of junction of the two rocks was therefore perfectly well defined. This inclusion, which has the appearance of a mica-schist or a highly micaceous gneiss, was found to be composed of quartz, felspar, and white and dark micas. Many of the crystals of felspar evidently belong to a triclinic species, while others exhibit cross striation when examined in polarized light. A few crystals of apatite were observed in sections prepared from this inclusion.

Another inclusion found in the granite of Sclattie has nearly the following dimensions—length 9 inches, width 7 inches, and thickness 3 inches. This specimen, which is exceedingly hard, is of a darker colour than the enclosing rock, and exhibits angles which are but slightly rounded. It is distinctly stratified by alternate bands of nearly colourless quartz and of some darker material, and the whole of its exterior is so covered by a layer of black mica as to render its separation from the surrounding granite an easy operation. Under the microscope this is seen to consist, to a large extent, of granular quartz, of which the outlines sometimes appear slightly rounded. With this quartz are mixed a few fragmentary crystals of felspar, of which some belong to a triclinic species, whilst others show cross striation when examined in polarized light. This specimen contains a considerable amount of brown or black mica; but white mica is also present, although in a less proportion. The quartz and mica occur in more or less distinct layers; and the black and colourless micas are much interfoliated, their laminæ being frequently enclosed in quartz.

* Haughton, Proc. Roy. Soc. vol. xviii. p. 313; Heddle, Trans. Roy. Soc. Edinb. vol. xxviii. p. 265, note.

† One very minute crystal only of sphene was observed in the sections examined.

The inclusions found in the grey granite at Dyce quarry, six miles north-west of the city of Aberdeen, are, for the most part, foliated subangular masses of a dark bluish-grey colour, not unlike the first of those described as having been obtained at Sclattie. They are all distinctly foliated, and, on sections being examined, are seen to be composed of quartz, felspar, aud the usual dark- and light-coloured micas; these inclusions also contain a few minute garnets, and a little magnetite, together with occasional needle-like crystals of apatite. Some of the bands of this enclosed rock are almost entirely composed of the two descriptions of mica, while others decidedly resemble gneiss in their constitution.

One of the most remarkable specimens from this quarry was in the form of a lenticular mass weighing considerably over a hundredweight, and so covered externally by a thin layer of mica that it readily separated from the enclosing rock. On being broken it was found to consist of a granite possessing the same characteristics as that around it, but at least one half finer in texture. Sections were prepared from the fragments, and were found to be composed of the same materials as the enclosing rock, with the addition of a little magnetite, the presence of which was not observed in the latter. Triclinic felspar (oligoclase) was also more than usually abundant.

At Kemnay, three miles west of the railway-station at Kintore, a quarry is extensively worked on a granite of the same general character as that wrought nearer the city of Aberdeen. In this locality inclusions are extremely rare; but one of the specimens there obtained is of great interest as affording evidence that some of the dark patches in granites, which at first sight closely resemble enclosures of a schistose rock, may in reality be the result of segregation.

Fig. 6, Pl. I., represents the specimen referred to, one half natural size.

Sections of the dark material forming the inclusion in this rock are, when examined under the microscope, found to be composed entirely of black and colourless micas with their planes of cleavage all lying approximately in the same direction.

The granite in this quarry is traversed by a dyke of very fine-grained black mica-trap, which has sometimes a thickness of several feet, but sends off various branches, some of which are not much thicker than cardboard. This trap is so firmly soldered to the enclosing granite that blocks of which one portion is granite and the other trap do not, when struck, show a greater tendency to divide along the junction than in any other direction. When cut perpendicularly to the plane of junction, the granite and trap are seen to be joined along a line as distinct as when two pieces of differently coloured wood are planed to a joint, glued together, and subsequently polished. Some small fragments of granite which have become enclosed in this trap are not in the slightest degree altered, and their edges are as sharp as when first separated from the parent rock.

Under the microscope this trap is found to consist of a crystalline felspathic ground-mass in which small flakes of dark mica and distinct crystals of felspar are porphyritically enclosed. The crystals of felspar usually show twinning; but the largest of them do not exceed ·2 millim. in length, while the flakes of mica seldom exceed ·15 millim. in diameter. In addition to felspar and mica this rock contains a few minute grains of magnetite.

The granites in the neighbourhood of Peterhead differ from those in the vicinity of Aberdeen in their dominant felspar being of a pinkish-red hue, instead of colourless or greyish-white, as in the last-named locality. These granites are regarded by Professor Haughton as being of eruptive origin, and their second felspar is albite*.

Under the microscope thin sections of the granite from this district are seen to consist of quartz, orthoclase, a subordinate amount of a triclinic felspar, black or very dark-brown mica, a few needle-like crystals of apatite, and occasional crystalline patches of titanite. In addition to these minerals, vermicular chlorite occurs in the granite of Black Hills, where the quartz also occasionally encloses filamentary crystals, which are perhaps rutile.

The principal quarries worked in the district are situated at Stirling Hill and Black Hills, a few miles south of the town of Peterhead. In both these localities the inclusions almost invariably assume an ovoid form, and usually vary in dimensions from the size of a nut to that of a large apple; considerably larger ones are, however, sometimes met with. They are in nearly all cases darker in colour and much finer in texture than the enclosing rock; their outlines are sharply defined, and they frequently enclose, porphyritically, rounded crystals of pinkish-red orthoclase.

Seven different sections were prepared of as many ovoid inclusions from this district, and in every instance they were found to consist of an exceedingly fine-grained granite containing all the various minerals present in the enclosing rock. The proportions of mica and of triclinic felspar are, however, greater than in the normal granite, and the amount of quartz is somewhat less.

This agrees with the results obtained by analyses of the average granite and of the dark-coloured rounded enclosures:—

	Granite.	Inclusion.
Water, hygrometric	·21	·19
Water, combined	·40	·76
Silica	73·70	64·39
Alumina	14·44	15·99
Phosphoric anhydride	trace	trace
Titanic "	distinct traces	distinct traces
Ferric oxide	·43	1·47
Ferrous "	1·49	5·98
Manganous oxide	trace	trace
Lime	1·08	2·57
Magnesia	trace	1·67
Potassa	4·43	2·46
Soda	4·21	4·96
	100·39	100·44
Specific gravity	2·69	2·73

* Proceedings of the Royal Society, vol. xviii. p. 313.

On comparing the foregoing analyses with those made of corresponding Cornish specimens (p. 8) it will be observed that the proportion of ferrous oxide as compared with ferric oxide is larger in the latter than in the former case. This, perhaps, in some measure arises from the black mica in the Peterhead granites being Haughtonite, a highly ferruginous mineral, in which the iron is mainly in the state of protoxide, and which Professor Heddle has shown to be present in many of the Scotch granites.

The only exception to the rounded form of inclusion observed in this district was found in a quarry at Black Hills, and is represented two thirds natural size in fig. 7, Pl. I.

Under the microscope this specimen is seen to be composed of a mixture of dark brown or black mica with granular quartz and an occasional crystal of felspar, the laminæ of the mica being so arranged as to produce foliation. A small quantity of magnetite or ilmenite is also present. In all rocks in which the mica in hand-specimens appears black, its colour in thin sections varies from brown to greyish brown.

Near the lighthouse at Buchan Ness this granite is traversed by a large dyke of micaceous felsite, which, in places, becomes porphyritic by enclosing crystals of quartz and orthoclase.

The granite of the Ardshiel quarries situated at Ballachulish, about ten miles south-east of Fort William, consists essentially of a fine-grained mixture of quartz, nearly colourless felspar, and dark mica, very closely resembling in general character the granites of the Mourne Mountains in Ireland. Under the microscope this rock is found, in addition to the minerals above enumerated, to contain hornblende, magnetite, sphene, and apatite; it is further observed that both orthoclase and a triclinic felspar are present.

This granite contains numerous inclusions which are often darker in colour than the enclosing rock, and frequently angular or sub-angular in form. Some of these have evidently the same general constitution as the enclosing granite, while others are manifestly enclosed fragments of foliated rocks. Ten thin sections of as many different inclusions from this locality were examined under the microscope with the following results:—

The non-foliated crystalline inclusions, some of which exhibit sharply defined angular outlines, were, without exception, fine-grained granites precisely resembling the enclosing rock in all respects, except in being finer in grain, in dark mica and hornblende being more abundant, and perhaps also in a somewhat larger proportion of triclinic felspar being present.

The enclosures exhibiting a decidedly schistose structure vary considerably in composition, and have obviously been derived from rocks differing both from one another and from the surrounding granite.

Such specimens are sometimes composed of granular quartz, a few fragmentary crystals of felspar, greenish-brown or nearly black mica, a little hornblende, occasional small garnets, and a little magnetite. In other cases hornblende and mica constitute a considerable proportion of the rock, and these are associated with granular quartz and fragments of felspar; besides which there are often traces of an amorphous felsitic ground-mass. Less frequently hornblende and mica decidedly predominate—quartz, a small quantity of felspar, garnets, and a little pyrites being also present. The hornblende and mica in such rocks generally enclose numerous granules of transparent quartz.

A fine-grained inclusion from this locality of over a foot in length is composed of contorted bands varying in colour from light grey to dark green. Under the microscope it is seen to consist largely of a mixture of colourless and dark mica and hornblende, with a few small garnets and a mineral which is probably sahlite, the shade of the several laminæ varying with the relative proportions of the different minerals present in each. This rock does not contain much free quartz; but a few small crystals of orthoclase and of a triclinic felspar, as well as a small amount of a felsitic ground-mass, are present.

The analysis of an average specimen of this inclusion afforded the following results (sp. gr. = 2·93):—

Water { hygrometric	..
Water { combined	·70
Silica	52·43
Phosphoric anhydride	trace
Alumina	12·76
Ferric oxide	1·34
Ferrous „	4·54
Manganous oxide	trace
Lime	14·16
Magnesia	9·75
Potassa	1·09
Soda	2·94
	99·71

In many granites inclusions occasionally take the form of more or less perfect crystals of felspar; and such specimens can only be regarded as being an extreme development of the enclosure of quartz and mica in crystals of that mineral. This inclusion of other minerals in felspar is a phenomenon well known to microscopical petrologists.

A good example of a pseudomorphic inclusion of this kind was brought by Mr. Merrifield from Glen Nevis, and on thin sections being examined under the microscope the granite and its included pseudomorph are found to consist of the same minerals in nearly similar proportions, except that dark mica is somewhat more plentiful in the latter than in the former. The minerals present, in both instances, are orthoclase, a triclinic felspar, dark greenish mica, hornblende, sphene, magnetite, and apatite.

Irish Granites.—The only Irish granites which I have examined are those of the north-eastern portion of the island; some of these are remarkable for the number and variety of the dark-coloured inclusions they contain, and they consequently afford unusual facilities for the study of such bodies.

The Newry granite is essentially composed of quartz, orthoclase, and black mica, and is usually made up of small and somewhat imperfect crystalline grains. It is, however, sometimes coarser in texture, and occasionally becomes porphyritic by enclosing fragments of felspar imbedded in a fine-grained ground-mass of a bluish-grey colour.

Near the Goragh-Wood railway-station granite is exposed for a length of over 400 yards and to a maximum height of above 20 yards. The rock is here principally of the description locally known as "white granite;" but close to the station it becomes porphyritic for a width of about 35 yards, and this "blue granite" is extensively quarried for ornamental purposes. It exhibits some slight indications of foliation, and its colour is due to the presence of numerous minute scales of black mica disseminated through the mass; the imperfect crystals of felspar, porphyritically enclosed, rarely exceed the dimensions of a small bean.

Immediately opposite the railway-platform the porphyritic granite terminates abruptly against beds of a fine-grained schistose rock, tilted at a high angle; this rock, which is above 60 feet in width, separates the blue granite from the ordinary white variety.

The granites of Newry, or Slieve Croob, are regarded by Prof. Hull * as being of metamorphic origin; and Mr. F. W. Egan, author of the memoir explanatory of the geological map of this portion of Ireland, believes them to be derived from Silurian rocks by transition through mica-schist and gneiss †. Mr. Kinahan, on the other hand, classes them with eruptive granites and describes the blue granite of Goragh Wood as an elvan which has come up through the Newry granite and must consequently be of more recent date ‡.

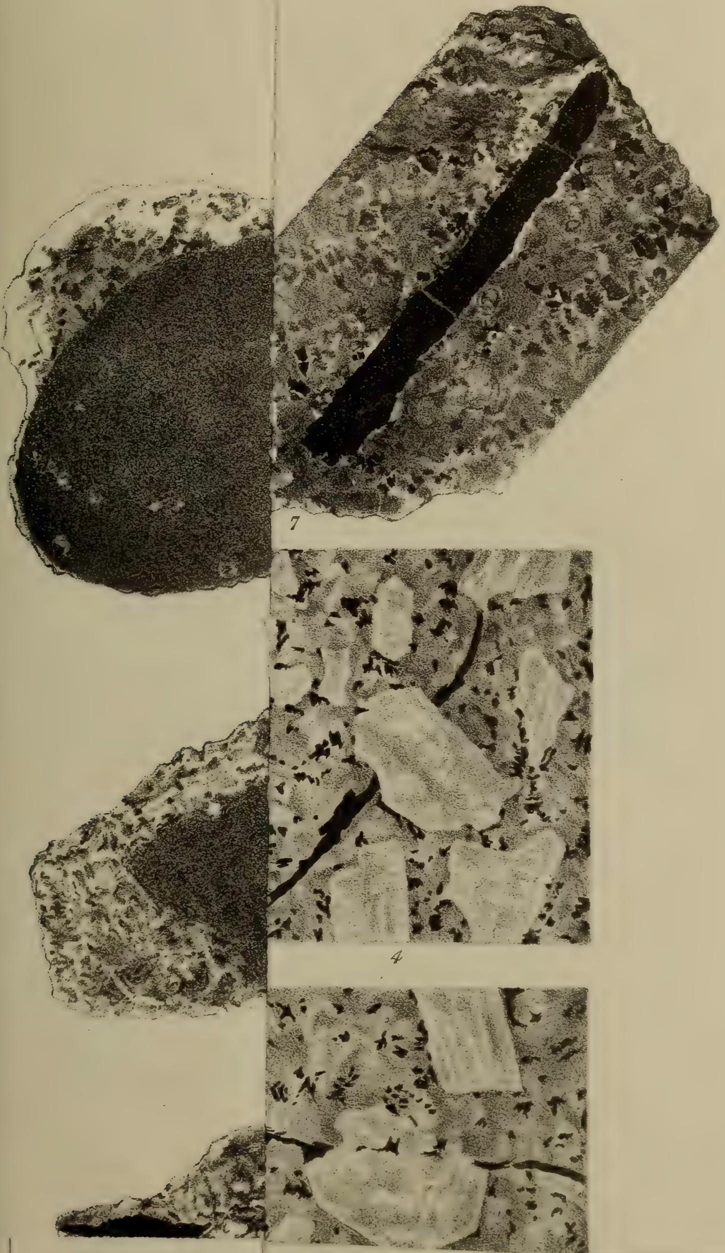
Examined under the microscope this granite is seen to be composed of quartz, orthoclase, a felspar exhibiting cross striation, a very few small crystals of a distinctly triclinic felspar, a dark or black mica, green hornblende, sphene, a few needles of apatite, with occasionally magnetite, pyrites, and perhaps a little rutile. A specimen of the schistose rock taken near the centre of the band against which the blue granite abuts, and consequently about 30 feet distant from the granite on either side, was found to be a fine-grained mica-schist. It is composed of finely granular quartz, occasional fragments of felspar, numerous minute nearly colourless garnets, small flakes of mica, usually of a dark colour, a little green hornblende, and a few spots of magnetite and pyrites.

A specimen of the same schistose rock obtained from its immediate junction with the blue granite is rather coarser in texture and is

* Building and Ornamental Stones of Great Britain &c., p. 45, note.

† Explanatory Memoir to accompany sheet 59 of the maps of the Geological Survey of Ireland, p. 12.

‡ 'Geology of Ireland,' pp. 209, 210.



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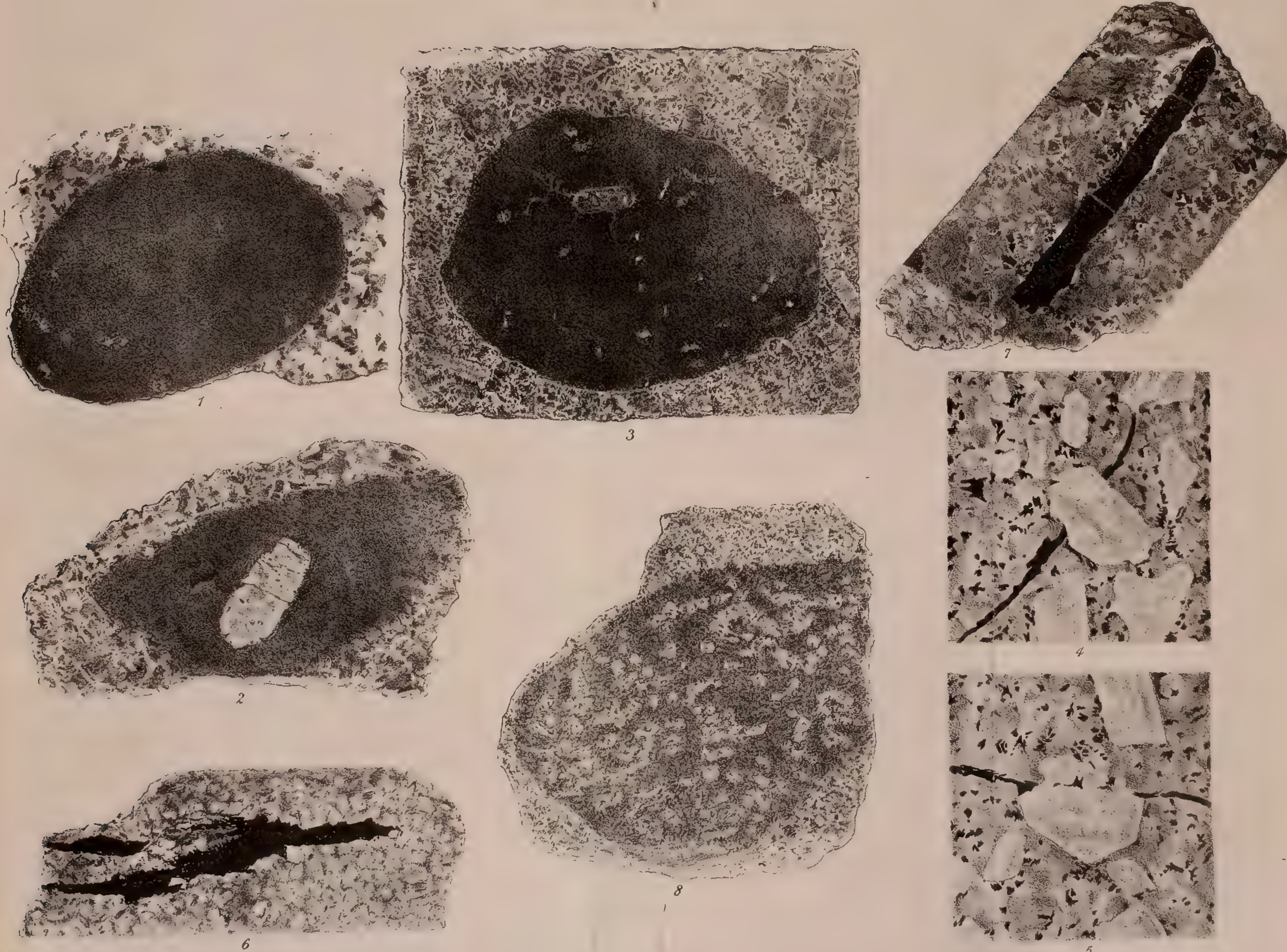


S. Foord lith. Hanhart imp.

INCLUSIONS IN GRANITE.

darker in colour than that at a greater distance from it, but does not otherwise differ, excepting that fragments of felspar are somewhat more numerous, and that the mica has become almost entirely replaced by green hornblende.

Some of the inclusions found in this locality are unquestionably fragments of a rock of the character of that exposed in the cutting opposite the railway-station. These, when of moderate dimensions, are generally almost black; and when thin sections of them are examined under the microscope they are found to consist of granular quartz with a few fragments of felspar, dark mica, green hornblende, often some minute garnets, crystalline patches of sphene, and occasionally a little pyrites.

When included fragments of this quartzose rock are of large size they, in the majority of cases, do not undergo alteration throughout, but are darkened by the presence of a disseminated material of a nearly black colour to a depth of about an inch only. In such cases the junction of the inclusion with the surrounding granite is perfectly defined, and the union of the two rocks is complete; but the disseminated dark flakes gradually become less plentiful, and towards the centre of the mass almost entirely disappear.

On examining thin sections of the interior or central portions of such inclusions they are found to be composed of a rock containing granular quartz, some felspar, numerous nearly colourless garnets, a little dark mica, a few flakes of hornblende, and occasionally specks of pyrites.

The exterior or altered portions are found to contain the same granular quartz mixed with a few fragments of felspar, much green hornblende porphyritically enclosing grains of quartz, some dark mica, a few small garnets, an occasional small crystal of sphene, and sometimes a little iron pyrites or magnetite.

The following analyses show the composition of the unaltered and altered rocks respectively:—

	Unaltered rock.	Altered rock.
Water { hygrometric	·13	·08
Water { combined	·38	·36
Silica	63·51	66·64
Alumina	13·42	13·77
Phosphoric anhydride	trace	trace
Titanic "	traces	traces
Ferric oxide	1·14	2·15
Ferrous "	3·91	3·68
Manganous oxide	trace	trace
Lime	10·80	6·08
Magnesia	3·03	3·42
Sulphur	trace	trace
Potassa	·23	·40
Soda	3·54	3·39
	100·09	99·97
Specific gravity	2·84	2·79

In addition to inclusions obviously derived from adjacent rocks, there are smaller ones of a somewhat similar dark shade, of which the origin is not so immediately apparent. When sections of these are examined under the microscope, they are found to be composed of granular quartz with a subordinate amount of felspar and a considerable proportion of dark mica; with these are associated crystalline patches of green hornblende porphyritically enclosing twinned crystals of felspar, occasional small garnets, and, exceptionally, minute crystals of sphene.

Besides included fragments of extraneous rocks, the Goragh-Wood granite encloses bodies which are apparently of concretionary origin. These comprehend all the constituent minerals of the surrounding rock, although not quite in the same proportions as in the normal granite, since they are sometimes of lighter colour, from the comparative absence of black mica, while in other cases they exhibit a dark shade in consequence of the greater abundance of that mineral.

Fig. 8, Pl. I., represents a concretionary enclosure in the Goragh-Wood granite, one half natural size. Thin sections of this specimen are found to be composed of quartz, orthoclase, triclinic felspar, black mica, sphene, a few needles of apatite, and some imperfect crystals of magnetite or ilmenite. In these spotted concretions the sphene is usually enclosed in white patches consisting of a mixture of felspar and quartz; and sometimes assumes the form of crystalline aggregations porphyritically enclosing either twinned crystals of felspar or irregular grains of magnetite. In coarse-grained granites concretionary inclusions sometimes affect the form of more or less imperfect crystals of felspar.

The porphyritic granite near Bessbrook, which has been opened out by extensive quarries, closely resembles that at Goragh Wood, and appears to be nearly free from inclusions of every description.

At Moor Quarry, 1½ mile south of Newry, the granite does not materially differ from that at Goragh Wood, except that, besides exhibiting less trace of foliation, it is somewhat lighter in colour and rather coarser in texture; under the microscope it is seen to have an essentially similar composition.

Similar inclusions to those found at Goragh Wood are of frequent occurrence in this granite; but those which appear to be of concretionary origin are relatively more numerous than in that locality.

All who have carefully examined the Mourne granite appear to agree with regard to its eruptive origin. Professor Hull further regards it as having been intruded among the stratified rocks in a state bordering on solidity, and with a temperature only sufficient to indurate, but not to metamorphose, the Silurian rocks by which it is surrounded *.

One of the most convenient localities from which unweathered specimens of this granite and its inclusions can be obtained is Ballymagreehan near Castlewellan, whence were procured the blocks which now form the base of the Albert Memorial in Hyde Park. This quarry is no longer worked, but the rock, which is of a brownish-

* Building and Ornamental Stones of Great Britain, p. 44.

grey colour, is finely granular and contains numerous dark inclusions.

When thin sections of this rock are examined under the microscope they are found to be composed of quartz, orthoclase, a triclinic felspar, which Prof. Haughton has determined to be albite*, a dark greenish mica, green hornblende, some needles of apatite, a little sphene, and occasionally magnetite or pyrites. The quartz of this granite is often traversed by minute hair-like crystals, which are perhaps rutile; and the hornblende and mica are so mixed as almost to suggest the possibility of one being sometimes an alteration-product of the other.

The inclusions in this rock are, as is usually the case in granites, of two kinds. The first variety is commonly more or less ovoid in form, is finer in grain than the surrounding granite, considerably darker in colour, and sometimes encloses crystals of orthoclase of considerable size. Such bodies contain all the constituents of the enclosing rock and, with the exception that dark mica is in considerable excess, they are present in nearly the same proportions.

Those belonging to the second category are angular or subangular in form, very dark in colour, and often exhibit a distinctly foliated structure. These are composed of granular quartz, black and greenish-black micas, green hornblende, a few imperfect crystals of felspar, specks of magnetite, with pyrites, and occasionally a little apatite. A few minute crystals are also sometimes present of a mineral which may perhaps be epidote.

General Conclusions.

The inclusions contained in granites are of two distinct kinds. Those of the first class are the result of an abnormal arrangement of the minerals constituting the granite itself; while those belonging to the second represent fragments of other rocks enclosed within its mass.

Inclusions of the first class are frequently, but not always, more or less ovoid in form, and are, essentially, composed of a fine-grained variety of the granite in which they occur; the proportion of triclinic felspar present in such granitic inclusions is often greater than in the rock which encloses them.

They are sometimes porphyritic in structure, and contain crystals of the characteristic felspar of the enclosing rock. Thus, when the felspar of the surrounding granite is either red or pink in colour, that which is porphyritically distributed in the inclusion will, as a rule, be correspondingly red or pink; whereas if white felspar be a characteristic of the ordinary granite, the porphyritic crystals of the inclusions will be likewise white.

The angles of felspar crystals so contained in inclusions are frequently much rounded, and the presence of a large proportion of

* Quart. Journ. Geol. Soc. vol. xii. p. 189.

mica or dark hornblende in such bodies often causes them to be of a deeper colour than the surrounding rock *.

In addition to their general similarity in mineral constitution to the adjoining granite, further evidence of the concretionary origin of such inclusions is afforded by the fact that a second similar nodule, differing from the first in colour or in fineness of grain only, is occasionally found within them.

Crystalline granitic inclusions not unfrequently assume the form of imperfectly defined crystals of felspar; these may be regarded as an extreme development of the well-known phenomenon of the enclosure of quartz and mica in felspar.

Another form of inclusion, giving rise to the production of a dark fissile patch in granite, results from a segregation of mica from the surrounding rock. An example of this kind of inclusion is seen in the granite from Kemnay, Scotland, fig. 6, Pl. I., where it will be observed that in the immediate vicinity of the enclosure the rock becomes comparatively free from mica.

The formation of rounded inclusions in granite is believed to have been usually contemporaneous with the solidification of the general rock-mass, and to be due to forces of the same nature as those which have resulted in the production of nodules in the well-known Napoleonite or orbicular diorite of Corsica. It is, however, probable that inclusions having a similar form may have been sometimes produced by the enclosure of pebbles of extraneous rocks.

In a few instances only have well-defined angular inclusions of a fine-grained granite been observed in granites of a coarser description; in some cases these may be enclosed fragments of an older granite, but in all the specimens which have been examined, such inclusions have invariably exhibited the distinctive characteristics of the enclosing rock.

Inclusions belonging to the second class are often schistose in structure and are usually irregular in outline, being sometimes traversed by veins of quartz, or divided by strings of granite, which appear to have filled spaces caused by the floating apart of slaty fragments in a granitic magma.

In many instances they are not materially altered, and in a majority of cases inclusions belonging to this class are easily recognized as being fragments of either gneiss, mica-schist, hornblende-schist, or garnet-schist; comparatively few specimens only have been met with so modified as to render their derivation difficult to determine.

Slaty inclusions are, as a rule, either highly micaceous or highly hornblendic; and an examination of the schistose rock in contact with the granite at Goragh Wood, and of partially altered inclusions from the same locality, shows that in that case the production of those minerals is a result of granitic contact †. It will be observed,

* When sections made through both a pebble-like inclusion and the enclosing granite are examined along their line of contact, minute crystals are observed to extend from the former into the latter.

† Mr. S. Allport has observed that in many cases slates in the immediate vicinity of the Land's-End mass of granite have become schorlaceous (Quart. Journ. Geol. Soc. vol. xxxii. p. 408).

on referring to the analyses p. 17, that the chief chemical changes which have taken place in the rock are an increase in the proportions of silica, iron oxides, magnesia, and potash, while there is a decrease in the quantity of lime.

Inclusions distinctly belonging to the two different classes not only occur in the same granites, but good examples of both descriptions may be sometimes found in the same cubic foot of rock.

When schistose inclusions are found in ordinary eruptive granites, they can only be regarded as fragments of extraneous rock which have been caught up by the granite and enclosed within its mass. In the case of granites which may, on the contrary, be supposed to be of metamorphic origin, they will doubtless be looked upon by those entertaining that opinion as portions of older rocks which have, to a great extent, withstood the action of granitic metamorphism.

The foregoing conclusions have been arrived at after an examination of only a limited number of rocks, but are probably capable of more extensive application.

EXPLANATION OF PLATE I.

Fig. 1. Ovoid inclusion from Gready quarry, Luxulyan, Cornwall, one half natural size. A fine-grained granite containing a large proportion of dark mica: p. 7.

2. Inclusion in granite from Foggen Tor, Dartmoor, natural size, porphyritically enclosing granular quartz and a large crystal of orthoclase, of which the angles are rounded: p. 8.

3. Ovoid granitic inclusion in granite from Shap, Westmoreland, enclosing a rounded crystal of red orthoclase, four tenths natural size: p. 9.

4. Inclusion in Shap granite, natural size, divided by a crystal of red orthoclase: p. 10.

5. A similar inclusion, natural size, in the same block of granite, passing in a broken line through a crystal of orthoclase: p. 10.

6. Segregationary inclusion of mica, one half natural size, Kemnay quarry, near Kintore: p. 12.

7. Schistose inclusion in red granite from Peterhead, Scotland, two thirds natural size, composed of dark mica, granular quartz, and a few crystals of felspar: p. 14.

8. Inclusion, one half natural size, in granite from Goragh Wood, Ireland. In the centre of each of the light-coloured porphyritic patches there is a crystal of sphene: p. 18.

Discussion.

The President said that he had examined cases of this kind in the Aberdeen granite, and had found that some were really fragments of another rock, and others concretionary. He therefore quite agreed in the limited observations with which Mr. Phillips had concluded from a much larger number. He thought the paper most valuable, especially as bearing on the temperature at which granite was formed.

Mr. Attwood remarked that on the western slope of the Wahsatch range, in Utah, these concretionary nodules were very common in the granites. Tunnels showed that they did not extend deep into the rock, but occurred only near the point of contact with other rocks.

Mr. Ormerod said he had observed these inclusions on the eastern side of Dartmoor; there the inclusions were generally oval, and called "mare's eggs," and the phenomena agreed with those described by Mr. Phillips.

Prof. Ramsay said these inclusions might be seen remarkably well on the steps of the Duke-of-York's column. The subject appeared to him to have been admirably worked out by Mr. Phillips. He thought, however, that Mr. Phillips's remarks were not inconsistent with the idea that some granites were metamorphic.

Mr. W. W. Smyth congratulated the author of the paper, with whom he heartily agreed. There were many cases to be seen in Cornwall of fragments torn off from the neighbouring rocks. When, however, you find aggregates, as of schorl, like balls, they must be due to some kind of concretionary action. The Elba granites showed a tendency to aggregation with schorl and with mica.

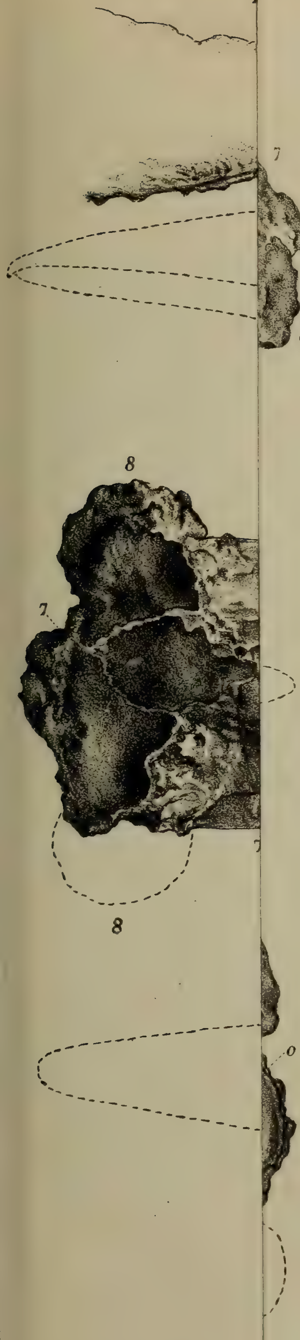
Prof. Seeley quoted cases from the internal structure of crystals of augite and hornblende of the Siebengebirge, where similar concretionary masses occur plentifully in the trachytic rocks. They generally have angular sides, as though large felspar masses had been altered and removed. They are mostly rich in augite, are often limited by a film of kaolin, and are quite as large as those in granite. He thought they were analogous to septarian concretions in clay, and due to the percolation of water removing materials from one place and putting them down in another.

Prof. Judd said Mr. Phillips had undoubtedly proved that there are two kinds of these enclosures in granite. He suggested that a third class might exist, namely, fragments brought up from below, like the nodules composed of augite, olivine, and enstatite, which are found in so many basic rocks.

Mr. Bauerman thought that no great dependence could be placed upon external contour as evidence of the local or foreign origin of an included mass, as in graphic granite the quartz might take the angles of the felspar or might be freely developed; then the rounded form of olivine masses might be due to interrupted development, and not to their being included fragments. He exhibited a piece of zircon syenite from Labrador; in it was a fragment, as it seems, of a hornblende and soda-lime felspar rock, which, on the other side, took a true crystal form of hornblende.

Dr. Hicks stated that sphene was common in the hornblende gneisses of Scotland. He had observed many cases similar to those described by Mr. Phillips, where the surrounding rock and included fragments were identical, and where there was but little alteration produced by the intrusion.

Mr. Phillips thought the disappearance of rounded fragments on sinking deeper in the rock, referred to by Mr. Attwood, was only an accident. He had found concretionary inclusions at all distances from junction-surfaces. He thought that fragments coming up from below, as referred to by Prof. Judd, would generally be dissolved or greatly diminished in size during their passage.



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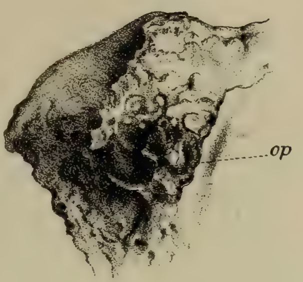

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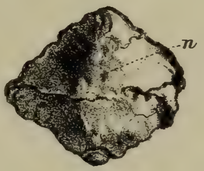

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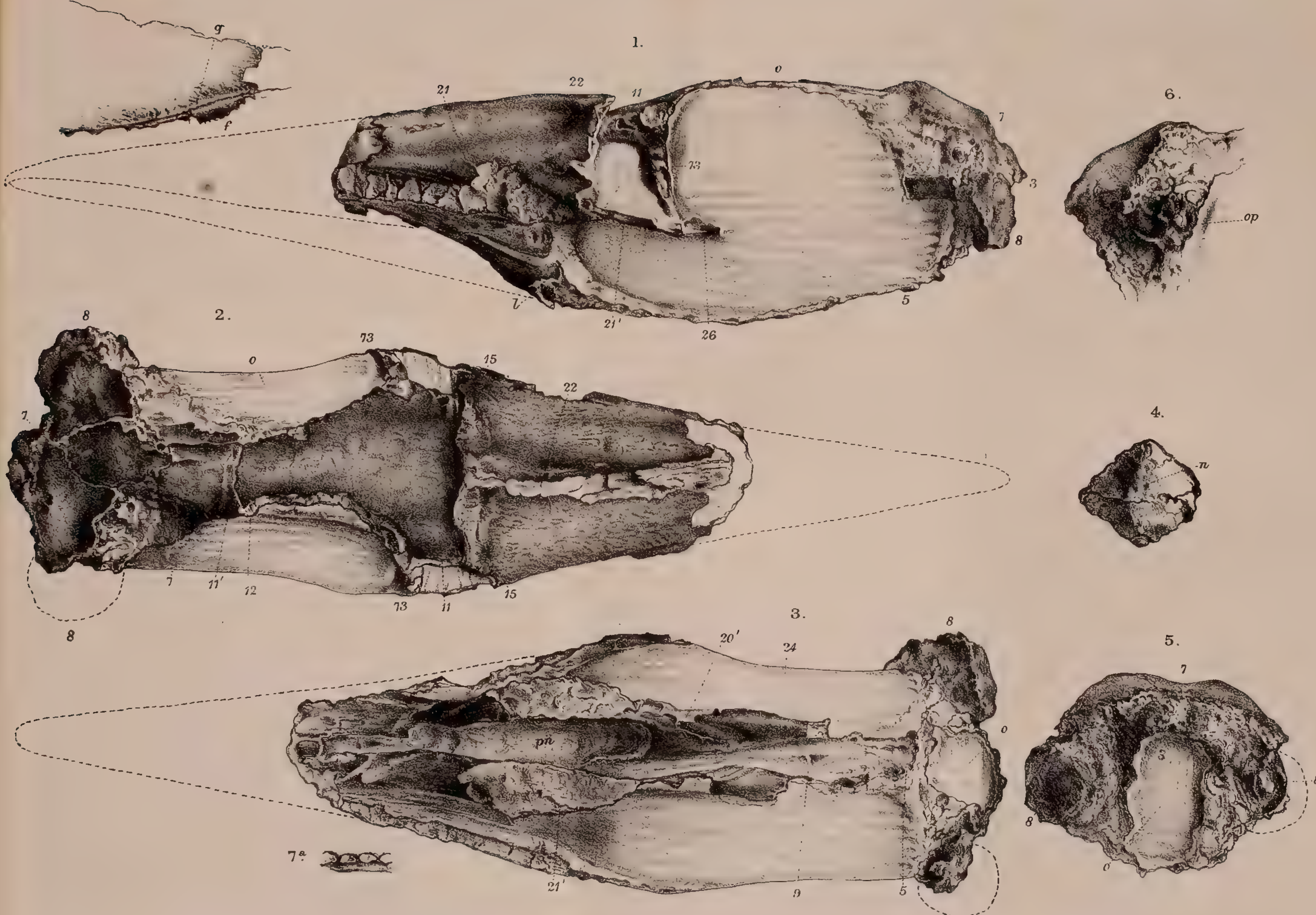
A. S. Foord. del et lith.

Mintern Bros, imp.



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SKULL OF ARGILLORNIS LONGIPENNIS.

2. *On the* Skull *of* Argillornis longipennis, *Ow.* By Professor Owen, C.B., F.R.S., F.G.S., &c. (Read November 5, 1879.)

[Plate II.]

I have been favoured by W. H. Shrubsole, Esq., F.G.S., to whom I was indebted for the humeral evidences of *Argillornis longipennis* *, with a fossil from the same formation and locality (London Clay, Sheppey), which, when cleared of matrix, has afforded the subject of the following description.

It is a considerable portion of the skull of a bird (Pl. II.), wanting the lower jaw and fore end of the upper jaw: some prominent parts are abraded, exposing a pneumatic cellular structure.

The length of the fossil is 5 inches 4 lines =135 millims.; the breadth across the lacrymals (fig. 2, 73) is 1 inch 9 lines =45 millims.; across the mastoids (ib. 8, 8) 2 inches =50 millims.; but these prominences have suffered abrasion.

The coalesced frontals (fig. 2, 11, 11′), which are 2 inches 6 lines = 63 millims. in length, have joined the præmaxillo-nasals (fig. 2, 15–22) by a transverse suture, 1 inch 2 lines =30 millims. in length. Posthumous pressure has driven this part of the frontal two or three lines below such base of the upper mandible (fig. 1, 11, 22).

Defining the hind part of the frontal by a faint linear trace of a fronto-parietal suture, 7, the breadth of the bone is here 1 inch 6 lines =37 millims. The whole of the preserved extent of the frontal is smooth, devoid of intermuscular crest or ridges, feebly convex behind the orbits, becoming as feebly concave transversely between the orbits—this concavity expanding as the bone advances and gains breadth, and the lateral surface becoming transversely convex where the frontal, 11, joins the lacrymal, 73 (fig. 2).

But a small proportion of the assumed parietal (fig. 2, 7) preserves its outer surface, which is smooth and unimpressed. That of the parieto-occipital, overarching the cerebellar prominence (fig. 5, 7–3) with the mastoid protuberance, 8, present only on the left side, as also that of the occipital boundary of the upper half of the occipital foramen, *o*, are represented by the remains of the cancellous structure. The basi- and paroccipitals are broken away. On the right side is preserved the thin convex inner plate of the cranial wall, which protected the optic lobe (fig. 6, *op*). The breadth of the foramen magnum (fig. 5, *o*) is 7 lines =15 millims. The depth of the cranium from the hind end of the frontal to the lower surface of the basisphenoid is 1 inch 6 lines =39 millims. The base of the post-orbital process, indicated on the right side (fig. 2, 12), and the cast of the orbit in the matrix (fig. 1, *o*), indicate the fore-and-aft diameter of that cavity as about 1 inch 6 lines. The slender descending process of the lacrymal (fig. 1, 73), 3 lines =6 millims. in breadth, is convex across, concave vertically; the upper expanded

* Quart. Journ. Geol. Soc. vol. xxxiv. 1878, p. 124, pl. vi.

part and the lower end of the bone are broken away on both sides. The prælacrymal vacuity (fig. 1, *l*) is arched above, and slightly expanded at the lower base, which is made straight by the narrow maxillo-malar bar, 21′–26; from this is continued a small portion of the suborbital part of the malar.

The constituents of the preserved basal portion of the upper mandible have coalesced into a bony roof, sloping from a ridge-piece, which soon becomes narrow as it advances from the fronto-nasal suture, 11–22. The short horizontal tract beyond the suture is divided from the sloping sides by a pair of low, short, oblique ridges (fig. 2, 15, 15), continued from the ends of the suture obliquely forward and inward. The roof gradually narrows from a basal breadth of 1 inch 6 lines to one of 11 lines, where the snout-end of the upper bill is broken away.

The sloping sides in advance of the ridges, 21, 22, fig. 1, are feebly concave along the upper half, and as feebly convex toward their lower border, which is traversed a little above the alveolar margin of the upper jaw by a longitudinal groove (fig. 7, *g*). This margin is broken away on both sides, and large cancelli of pneumatic character are exposed.

At one short tract on the right side (ib. *f*), which appears to be the uninjured alveolar border, there are the outlets of four small vertical pits, like the sockets of teeth, but filled with matrix. Of this portion a magnified view is given at fig. 7 *a*, Pl. II. The part is, unfortunately, wanting on the opposite side, and along the rest of the fractured alveolar borders on the right side (fig. 7) of the upper mandible. The fractured fore end exposes a nasal cavity, *n*, fig. 4, below which is the widely cancellous structure of the palatal floor, beneath the middle of which, in a longitudinal groove, is a small portion of bone, *p*.

The fractured cancellous tracts of the alveolar borders of the upper bill I take to be the base of those borders which, when entire, contracted to a narrow margin, possibly dentigerous, and were divided from the palatal surface by a longitudinal groove, the mesial side of which was continued into a palatal tract, descending some way below the alveolar border, and terminating in the ridge bounding the side wall of a long and narrow mesial palatal vacuity—the *palato-naris* (fig. 3, *pn*). The suture indicating the proportions respectively contributed by the maxillary and palatine bones is well marked on both sides; and, after a course from behind forward of 15 millims., the fore end of the palatine underlaps the broadening part of the maxillary plate. In advance of the palatines, the maxillo-præmaxillary portion of the palate is a continuous roof of bone, longitudinally grooved at the mid line, at the fore end of which is the fragment of bone above noticed. The exposed palatal surface of the palatine gradually expands to a breadth of 10 millims., and as gradually contracts to where it changes the horizontal for the vertical direction, bending forward anteriorly to bound the palato-naris, and thence continued backward to apply itself to the inner side of the fore part of the pterygoid, 24. The length of the palatine is 2 inches 6 lines =63 millims.; the length of the palato-naris, *pn*, is 1 inch 7 lines =40 millims.; the extreme breadth of this opening is 5 lines =10 millims. It is closed behind by the præsphenoidal rostrum, 9, fig. 3, which is wedged between the bones 24′ & 20′.

The most prominent character of this part of the bony palate preserved in the present ornitholite is the degree in which it descends below the level of the alveolar border to form that of the palato-naris. In this character I find the nearest approach to the Albatross (*Diomedea exulans*). In this bird, along nearly the hinder half of the upper bill, the palatal process of the maxillary forms a ridge, divided by a groove or channel from the alveolar border, which channel gradually widens and deepens, chiefly by the descent of the ridge below the level of the alveolar border, opposite the termination of which the maxillary palatal ridge becomes obtuse, and is flattened and expanded where it is underlapped by the fore end of the palatine. If the alveolar ridge was shaved off short of the bottom of the groove, so much of the groove as is left in the ornitholite between the outer fractured border and the inner downsloping maxillo-palatine bones would be represented. But the palatine part of the maxillary forms no ridge in the fossil; the flattened surface is continued forward in advance of the underlapping part of the palatine bone. In the Pelican the downwardly produced parts of the palatines are posterior to the palato-naris. The Albatross among existing birds presents the nearest, though a remote, resemblance to the palatine characters of *Argillornis*.

From *Diomedea*, *Argillornis*, like *Odontopteryx**, differs in the absence of the basirostral external nostrils and of the superorbital gland-pits. It resembles *Odontopteryx* in the absence of mesial or lateral ridges, indicative of the temporal fossæ, which characters are strongly marked in the Cormorants and other Totipalmates lacking the superorbital gland-pits. The fore part of the long frontal is relatively broader in *Argillornis* than in *Odontopteryx*, and the fronto-nasal suture is consequently more extensive. The upper tract of the upper bill is less defined than in *Argillornis*; the basilateral tract leading to the hinder commencement of the longitudinal lateral groove is broader or deeper. This groove, commencing, as in *Odontopteryx*, below the prælacrymal vacuity, runs along nearer the alveolar border than in *Odontopteryx*. The state of the latter fossil precludes a comparison of the palatal structures; and the circumstance that the specimen is unique forbids the making of sections of the more important parts which such comparison would require.

I have remarked in a former paper † that the skull of *Odontopteryx* seems too small for a bird with a wing-bone of the size of that of *Argillornis*; but this objection does not apply to the present cranial fossil.

The length of this cranium from the upper border of the occipital foramen to the fore border of the prælacrymal vacuity is 3 inches

* Quart. Journ. Geol. Soc. vol. xxix. 1873, p. 511, pls. xvi. & xvii.

† Ibid. vol. xxxiv. 1878, p. 128.

6 lines; the same admeasurement in *Odontopteryx* gives but 2 inches 6 lines. I estimated the total length of the latter's skull at 5 inches 6 lines. Completing on the same scale the broken beak of *Argillornis* (Pl. II. fig. 1), the skull gives a length of 7 inches 6 lines. The degree in which the wing-bones of *Argillornis* resembled those of *Diomedea* is so nearly that in which any resemblance can be pointed out in the cranial fossil to the skull of the Albatross amongst existing birds, that the probability of the cranial and humeral fossils belonging to the same bird or species of bird from the Sheppey locality of the London Clay appears to me to justify the reference of the present fossil to *Argillornis longipennis*. If such a skull should be hereafter discovered associated with the rest of the skeleton, in this or any other locality, so as to disprove such supposed generic or specific agreement, the name *Macropteron* may, perhaps, be accepted by the fortunate describer of such fossil remains of a new genus.

EXPLANATION OF PLATE II.

Fig. 1. Side view of skull of *Argillornis longipennis*.
2. Upper view of the same.
3. Under view of the same.
4. Anterior fractured surface of upper bill.
5. Posterior surface of cranium.
6. Exposed part of inner wall of cranium, lodging the optic lobe, *op*.
7. Outline of part of the right side of the upper jaw.
7 *a*. Magnified view of the alveolar surface of the small entire part, *f*, of that side.

All the figures, save 7 *a*, are of the natural size.

Discussion.

Prof. Seeley remarked upon the disadvantage under which the Fellows of the Society laboured in attempting to discuss the subject when the specimen was not before them. The diagrams, as he pointed out, differed from the description in many important parts. If Prof. Owen's description was rather to be relied upon, he argued that the analogy with the Albatross was not made out. He should have liked to know the evidence on which the skull was associated with the limb-bone.

Mr. Hulke stated that the diagrams exhibited were very accurate and intelligent copies of Prof. Owen's sketches.

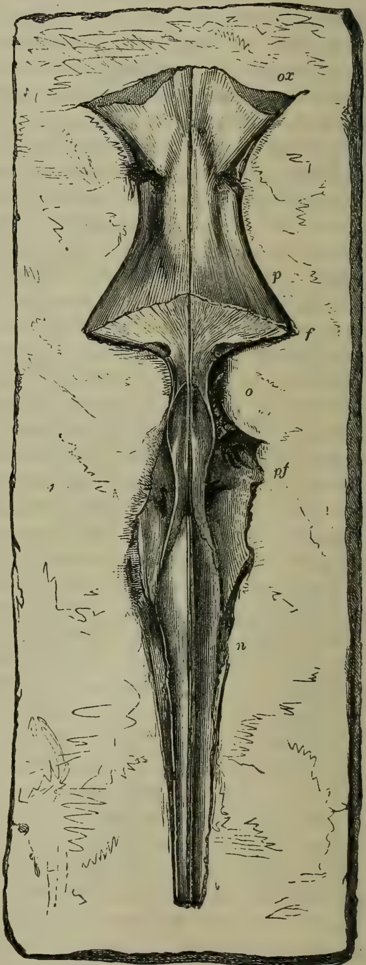
Mr. W. Davies and Dr. Woodward stated that the fossil, which they had both seen, greatly resembled, in general character, the skull of the Albatross.

3. *On* RHAMPHOCEPHALUS PRESTWICHI, *Seeley*, *an* ORNITHOSAURIAN *from the* STONESFIELD SLATE *of* KINETON. By H. G. SEELEY, Esq., F.R.S., F.G.S., Professor of Geography in King's College, London. (Read June 25, 1879.)

PROF. PRESTWICH has obtained from the Stonesfield slate of Kineton, near Stow-on-the-Wold, a small slab which makes a valuable contribution to our knowledge of the structure of the skull in Ornithosaurs from the British Lower Secondary rocks. This specimen is little more than a cast from the upper surface of the cranium, not unlike in general character to the form originally described by Goldfuss as *Ornithocephalus Münsteri*. The skull itself was unfortunately in the corresponding slab, which has not been preserved; but a few slight fragments of bone remain sufficient to show the dense osseous tissue which is usual in Pterodactyles. The specimen yields a clear impression, which displays the proportions of the cranial bones, and the sutures between them, in a way so distinct as to enable me to state that this animal was certainly different generically from every other type which has hitherto been described. Whether, however, it pertained to a distinct species from those indicated by the fossils from Stonesfield which have already been figured by Professors Huxley and Owen is a matter upon which some doubt may be felt; but bearing in mind the relatively large size of the jaws and teeth in those fossils, I am strongly of opinion that this specimen indicates a smaller kind of animal, in which the dentary apparatus was less developed, and I therefore venture to suggest for it a specific name.

The remarkable feature which leads me to consider this specimen to be the type of a new genus is its singular analogy to the Crocodilian skull, which has never been displayed to the same degree in any other Ornithosaur. The fragment shows the parietal, frontal, prefrontal, and nasal bones; all these are arranged on the Crocodilian plan, and yet the proportions of the parietal and frontal regions are in no respect those of a Crocodile. All the bones are smooth on the upper surface. The parietal region is long, flattened above, slightly convex in length, with a moderate median depression posteriorly, where there are some longitudinal striations, as though the end of a supraoccipital here overlapped the parietal bone; but the bone terminates transversely in a sharp clean posterior edge, which is sinuous, being convex in the middle and concave towards the sides, where the bone widens out, giving off lateral wings towards the squamosal region. The median suture of the parietal bones can be traced, though it is not quite in the middle line. The bones become constricted from side to side, the constriction being greatest behind the middle, where they appear to be naturally notched on each side. I do not see the signification of these notches, unless they indicate the anterior termination of squamosal bones which overlapped the posterior portion of the parietals and curved with them backward and outward. There is on the lateral portions of the parietal a slight impression of the bone, which also suggests to me this interpretation. The parietal (*p*) terminates anteriorly in a transverse suture in which it joins the frontal bones (*f*); this suture is nearly straight, being curved slightly backward. The length of the parietal bone is exactly 3 centimetres; its posterior width, as preserved (which is less than the real width), is about 25 millimetres; the greatest constriction of the bone from side to side just in front of the notches appears to be about 8 millimetres or rather more, while the anterior width of the bones at their union with the frontal bones is 23 millimetres.

Cast of upper surface of Skull of Rhamphocephalus Prestwichi, *natural size.*



ox, articular surface for occipital bone *p*, parietal; *f*, frontal; *o*, orbit; *pf*, prefrontal; *n*, nasal.

There is a moderate transverse depression on the skull where the parietal bones join the frontal. Unfortunately there is no indication of the character of this long cerebral region, though it is evident that there was a concavity below the slender squamosal arch. The parietal appears where it joined the frontal bone to have given attachment to the postfrontal, at the back of the orbit, in the usual way; but, apparently from the sharp downward curve of the postfrontal bone, no trace of it is preserved. The width of its union with the roof-bones of the skull was about 5 millimetres. The frontal bones measure in length 18 millimetres, are greatly constricted in the orbital region and cupped with almost semicircular borders for the orbits. The width of the interorbital part of the bones is 5 millimetres, and the extent of the bone posterior to the orbit at its outer border is 4 millimetres. The bone widens in front a little, but the front of the orbit is formed, as usual, by the prefrontal bone (*pf*). The median suture between the frontals is clear. There is a deep concavity between the orbits in front, which is formed by the margins of the frontal bone being elevated so as to form an upper orbital border, which recalls the condition in Crocodiles. There are also elevated ridges behind the orbits. The little that is seen of the inner orbital border is smooth, vertical, and concave in length. The orbits appear to have been oblique and to have looked upward and forward. The length of that on the left side is about 16 millimetres. The frontal bone (*f*) terminates anteriorly in a forked suture, which receives the ends of the nasal bones (*n*) in the middle, and the prefrontal bones (*pf*) on the oblique external margins. The prefrontal bones, however, are not very distinct from the nasal bones, though the suture appears to run on the inner side of sharp ridges which form their inner borders. But of this I cannot speak positively, as the anterior termination of the suture cannot be distinguished.

These prefrontal bones (*pf*), or prefrontal elements of the nasal, are channelled in length; they reach backward to the orbit and are about 2 centimetres long. The exact width of the specimen in front of the orbit does not represent the width of the bones during life. As preserved, the width is not more than 16 millimetres. During life the width may have been 2½ centimetres. The nasal bones, as preserved, are 56 millimetres long. Where they join the frontal elements they are about 4 millimetres wide. They attain their greatest width where the slightly diverging prefrontal ridges terminate on their sides, and are there about 9 millimetres wide at rather more than a centimetre from the frontal suture. The longitudinal median suture between the nasal bones is well marked and wider than in the frontal region; yet the nasal bones form an elevated median keel slightly convex in length and defined by a well-marked channel on each side. The bones converge slowly anteriorly and may have extended a little further than is indicated by the specimen, if they terminated in a point. The circumstance that the maxillary bones are not preserved is strong presumptive evidence that the maxillaries were vertical, or at least formed a sharp angle with the roof of the skull. It is perhaps remarkable that no portion of the nasal bones can be identified as having entered into the external nares, though in many Pterodactyles, such as *Cycnorhamphus suevicus*, there is no lateral indentation of the bones in the nasal region. If we were to regard these nasal bones as having extended to within an inch of the extremity of the skull the total length of the head would not have been more than 5½ inches, and the toothed portion of jaw would probably not have exceeded 2 inches. The teeth I should infer to have been of about the size of those of *Cycnorhamphus suevicus* of Quenstedt, which stood about 15 inches high.

The characters which especially distinguish this animal are, first, the remarkable length of the roof of the skull, posterior to the orbits (*o*), which amounts to about 38 millimetres; so that if the orbits bounded the anterior part of the cerebral region, as is usual in Pterodactyles, there is here evidence of a cerebral elongation to which no other Pterodactyle even approximates; and it is difficult to believe that a brain-cavity so long and narrow, as shown by the median constriction, could have contained a brain of Avian plan such as is evidenced by almost every specimen from Solenhofen in which an internal mould of this region is preserved, as may be seen in the museums at Munich, Heidelberg, and Haarlem.

Secondly, I do not remember in any other Pterodactyle any thing like so great a constriction of the frontal region between the orbits; thirdly, the sutures between the bones are better marked than in any other Pterodactyle which I have examined; and, fourthly, the plan of structure of the roof-bones of this skull is so entirely Reptilian as to suggest the existence of Ornithosaurian animals of lower grade than any which I have hitherto seen. The slender material does not, however, justify speculation; and it is quite possible that this may prove to be a genus closely allied to some of those animals for which the name *Rhamphorhynchus* has been appropriated; and I shall be quite prepared to find that all the Ornithosaurians from Stonesfield belong to this or an allied genus which had *Rhamphorhynchus* for its nearest ally, and which resembled that genus in the characters of the postorbital arches.

There are indications, however, in the Stonesfield fossils of important differences from the German types now included in *Rhamphorhynchus* in the characters of the mandible and dentition, and the relatively large size of the hind limbs, the femur being, in one of these animals, 94 millimetres long, while the tibia has a length of 90 millimetres. This is far beyond the size of any species of *Rhamphorhynchus*, and, indeed, is only to be paralleled in *Dimorphodon* and the larger short-tailed German Pterodactyles, which have long hind legs and form the genus *Cycnorhamphus*. The wing-phalanges in these Stonesfield animals are, however, unusually long, longer than in any German species except perhaps *Pterodactylus vulturinus*, which is imperfectly known. The first phalange of the wing-finger of the largest Stonesfield specimen is nearly 5 inches long, while the second and third phalanges measure about $7\frac{3}{4}$ inches each, while the fourth is $6\frac{1}{2}$ inches long. But the Oxford specimens appear to indicate, from the different proportions of cervical vertebræ, lower jaws, and bones of the fore and hind limb, two or three well-defined species. To these may be added another from the Great Oolitic of Sarsden, of which the mandible has already been figured in this Journal by Prof. Huxley*. Although in the latter specimen nearly the whole skeleton appears to have occurred in the same spot, no trace of a long tail of the *Rhamphorhynchus* type has been met with. Among the Stonesfield specimens the sacrum consists of at least five vertebræ, and there are cervical and dorsal vertebræ, including the atlas, which apparently is not ankylosed to the axis, but no trace of a tail. These facts, taken in conjunction with the relatively large size of the hind limb and sacrum and the cranial differences, will, I believe, justify me in instituting a new genus for this cranium and the other Stonesfield Ornithosaurs.

* Quart. Journ. Geol. Soc. vol. xv. p. 658.

4. Supplementary Note *on the* Vertebræ *of* Ornithopsis, *Seeley*, = Eucamerotus, *Hulke*. By J. W. Hulke, Esq., F.R.S., F.G.S. (Read November 19, 1879.)

[Plates III. & IV.]

At the close of last session I brought before the Society some additional evidence of the existence in our Wealden times of a huge Dinosaur whose vertebræ were characterized by marvellous lightness; and I endeavoured to show, by an examination of all the material at that time available for comparison, that although the vertebræ of this Saurian (*Ornithopsis*, Seeley, *Eucamerotus*, Hulke; *Bothriospondylus*, in part, *Chondrosteosaurus*, Owen) exhibited correspondences with those of certain newly discovered American forms (some of which had been recently noticed by Prof. Owen) which indicated affinity with these, yet there coexisted such differences as seemed to me to disprove their generic identity.

The liberality of the Rev. W. Fox now enables me to place before you photographs and drawings which, for the first time, afford complete information respecting the structure of the vertebral column in the neck and trunk of this remarkable animal.

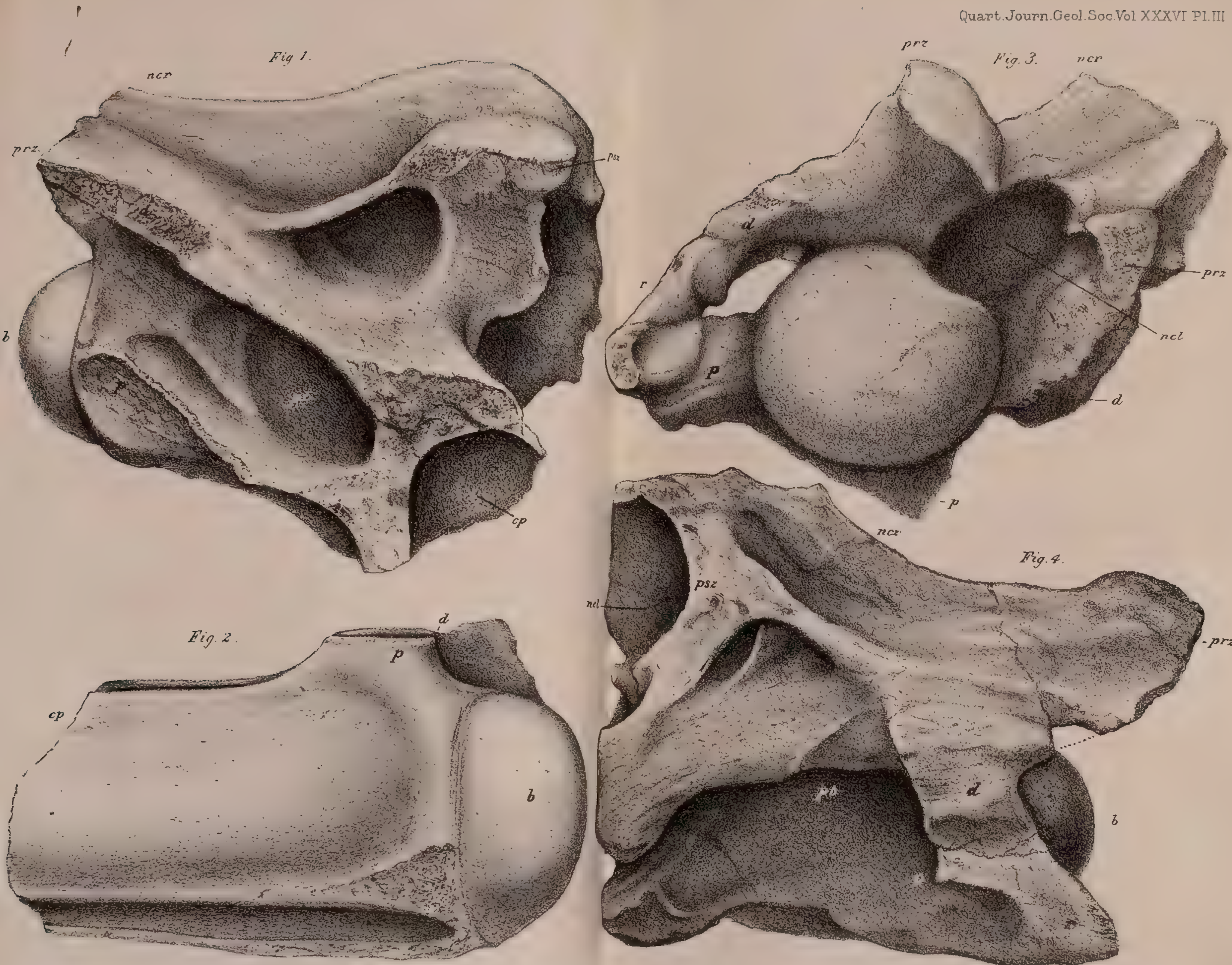
Neck.—Three cervical vertebræ in Mr. Fox's possession show the centrum in this region to be strongly opisthocœlous. The articular ball in this region is a larger portion of a sphere than in the trunk, and the cup is correspondingly deeper. The under surface of the centrum is singularly flat, a character which disappears in passing backwards and is little apparent in the trunk. The neural canal is very capacious. The præzygapophyses project considerably forward beyond the front of the neural arch, overhanging here the ball. Their articulating surface is large, of a roughly oblong form, and directed upwards and inwards. It is a single surface for each præzygapophysis; and the notch between the præzygapophyses is non-articular. The additional articular surface forming the zygantral arrangement present in dorsal centra is here absent; and the associated zygosphenal bolt dependent from the confluent inner ends of the postzygapophyses is necessarily also wanting in the neck. The neural arch in all Mr. Fox's specimens referable to the neck is devoid of spinous process. From the root of each præzygapophysis a lofty crest curves upwards, backwards, and inwards, and then diverges and declines posteriorly, where it ends in a stout postzygapophysial process bearing on its under and outer surface the articular facet. The crests of opposite sides are separated by a mesial groove very deep in front. There are two transverse processes, a lower on the body and an upper on the arch. The lower transverse process (parapophysis) springs from the side of the centrum towards the front, a constriction separating it from the articular ball. From the parapophysis a projecting ledge-like plate passes backwards along the centrum to its posterior border. The upper transverse process (diapophysis) springs from the arch vertically over the lower, towards which it inclines; and both processes are joined by the branches of a short forked riblet, which assist to enclose a large foramen. The only riblet preserved is mutilated; but it is evident that its unattached, free, distal border was extended forwards and backwards in a direction nearly parallel with the vertebral column in an ordinary manner. From the root of the diapophysis another projecting ledge-like plate descends along the side of the arch towards the junction of this with the centrum near the posterior border of this latter, thus taking a direction approximately parallel with the lower plate. Between these two plates, and much overhung by the upper one, the side of the centrum is impressed with a long narrow pit, crossed slantingly and imperfectly subdivided by ridges. From each of the neural crests, where these diverge behind, a prominent ridge runs downwards and forwards towards the root of the diapophysis of the same side, and another wider ridge descends nearly vertically towards the centrum, its posterior margin forming the lateral boundary of the posterior opening of the neural canal. Between these two ridges, and above the diapophysial ledge-plate which bounds it below, is a large very conspicuous depression. The average length of the three cervical centra was probably not under 28 centim., which is about the length of the centrum I brought before the Society last June. The large extent of the articular surfaces, the crests and ridges, and the great length of the vertebræ indicate a very long, extremely mobile, strongly muscular neck. In the singular flatness of the under surface of the centrum there is a striking resemblance to that of *Apteryx Mantelli*.

Trunk-Vertebræ.—The best-preserved vertebra in Mr. Fox's collection (Pl. III. figs. 4, 5) referable to the trunk is, I believe, from nearly the same situation as the neural arch I brought under the Society's notice in 1870. When placed on a plane surface, its height, taken from this to the top of its spinous process, is about 62 centim. The centrum is opisthocœlous; but the prominence of the articular ball is less than in the neck. The horizontal diameter of the ball is greater than the vertical diameter, the actual measurements being 22·5 centim. and 14·6 centim. The length of the centrum taken along the side from the base of the ball to the edge of the cup is, in the present state of the fossil, 17·5 centim.; but before abrasion it was probably not less than 20 centim. The under surface of the centrum is flattened transversely, but to a much smaller degree than in the neck. Longitudinally it is rendered very concave by the swelling of the articular ends. It is marked by a low median ridge. In the side of the centrum is the conspicuous opening of the large internal chamber, described more particularly in my last note. It is of an oval form, with the larger end in front. Its length is 13·5 centim., and its greatest vertical diameter is 5·4 centim. The chambers of opposite sides are separated only by a very thin median partition. The neurapophyses have an extensive attachment to the centrum, their antero-posterior extent nearly equalling that of the latter. They then contract to 13 centim. at a height of 1·5 centim.

to 2 centim. above the floor of the neural canal, and above this again rapidly increase. The arch and processes exhibit the singularly complex structure, less perfectly shown in my first fossil, shown here in 1870. The inner aspect of each præzygapophysis has an additional articular surface which, prolonged into the bottom of the deep notch that separates the pair of præzygapophyses, forms with this a zygantral arrangement. In correspondence with this a vertical zygosphenal bolt-plate depends from the confluent inner ends of the postzygapophyses. From the bottom of this zygosphenal plate two sheets of bone descend upon the neurapophyses, roofing in, after the fashion of an eave, the posterior opening of the neural canal. The præ- and postzygapophyses are connected by a platform continued along the neural arch in the level of its crown. This platform is produced outwards and upwards in the form of a strong and rather long transverse process, the free end of which is stout and clubbed as for the attachment of a rib-tubercle. Below, a thin vertical plate descends from the transverse process and platform upon the side of the neural arch, on which it is lost slightly below the mid height of the latter. Above, a similar thin plate connects the platform with the neural spine. The articular surface for the rib-head is just outside the præzygapophysis. Under the platform are very deep cavern-like recesses. The neural spine arises by two pairs of plates, of which the front are thinner, and spring from the crown of the very lofty arch close to the præzygapophyses. Below, these anterior plates are separated by a deep mesial groove. Above, they gradually approach, the separating groove lessens till they meet, when they again diverge and lose themselves in the anterior aspect of the transversely extended free end of the spinous process. The posterior pair, stouter, more pillar-like, arise directly over the postzygapophyses. They are not traceable so high as the anterior pair. Below, between them, immediately above the zygosphenal plate, is a deep pit. Above this they are separated by a narrow median crest which ascends nearly to the top of the spinous process, and served for the attachment of an interspinous ligament. The transverse expansion of the free end of the spinous process, so that the direction of its greatest measurement here crosses the axis of the vertebral column, and its deep sculpturing, are two remarkable features.

Until now our ideas of the form of these singular vertebræ had been drawn constructively from fragments of detached arches and centra. The association of arch and centrum, which in 1870 I felt justified in affirming, on the evidence of such fragments, is here first actually demonstrated in this magnificent fossil. Another centrum, apparently from the same part of the vertebral column as that just described, is 24 centim. long. The articular ball is 22 centim. in its vertical diameter, and 16 centim. in the horizontal. The under surface of the centrum is somewhat flattened. The chambers and their lateral openings are very large. A third centrum, about 23 centim. long, has a more cylindroid figure; the under surface is only very slightly flattened. The lateral opening and the chamber are smaller. I am inclined to regard this centrum as having occupied a position in the vertebral column posterior to the two just described. The form of the articulations and the superadded zygosphenal arrangement are calculated to greatly limit the mobility of the vertebræ on one another in this region. With respect to the orifice of the large-sided chambers in these vertebræ, Prof. Seeley, finding them paralleled in birds and Pterosauria, regarded them as pneumatic. Prof. Owen, on the other hand, thinks that they were more probably filled with chondrine; and in a recent discussion he supported this view by a reference to the vertebræ of fish. On this hypothesis it is not apparent to me why the chambers should attain their maximum development in the fore part of the trunk, be absent from the neck, and lessen towards the loins. Why should such a connective substance as chondrine be thus limited in its skeletal distribution? Rather does not such limitation strengthen the opinion of their being air-chambers? In Birds, particularly those endowed with great powers of flight, *e. g.* Albatross, the pneumatic opening in the side of the vertebral centrum is largest precisely in the same situation as in *Eucamerotus*; it is also wanting in the neck, and it rapidly lessens towards the sacrum. In noticing this parallel I would, however, not be understood to affirm that *Eucamerotus* was capable of flight.

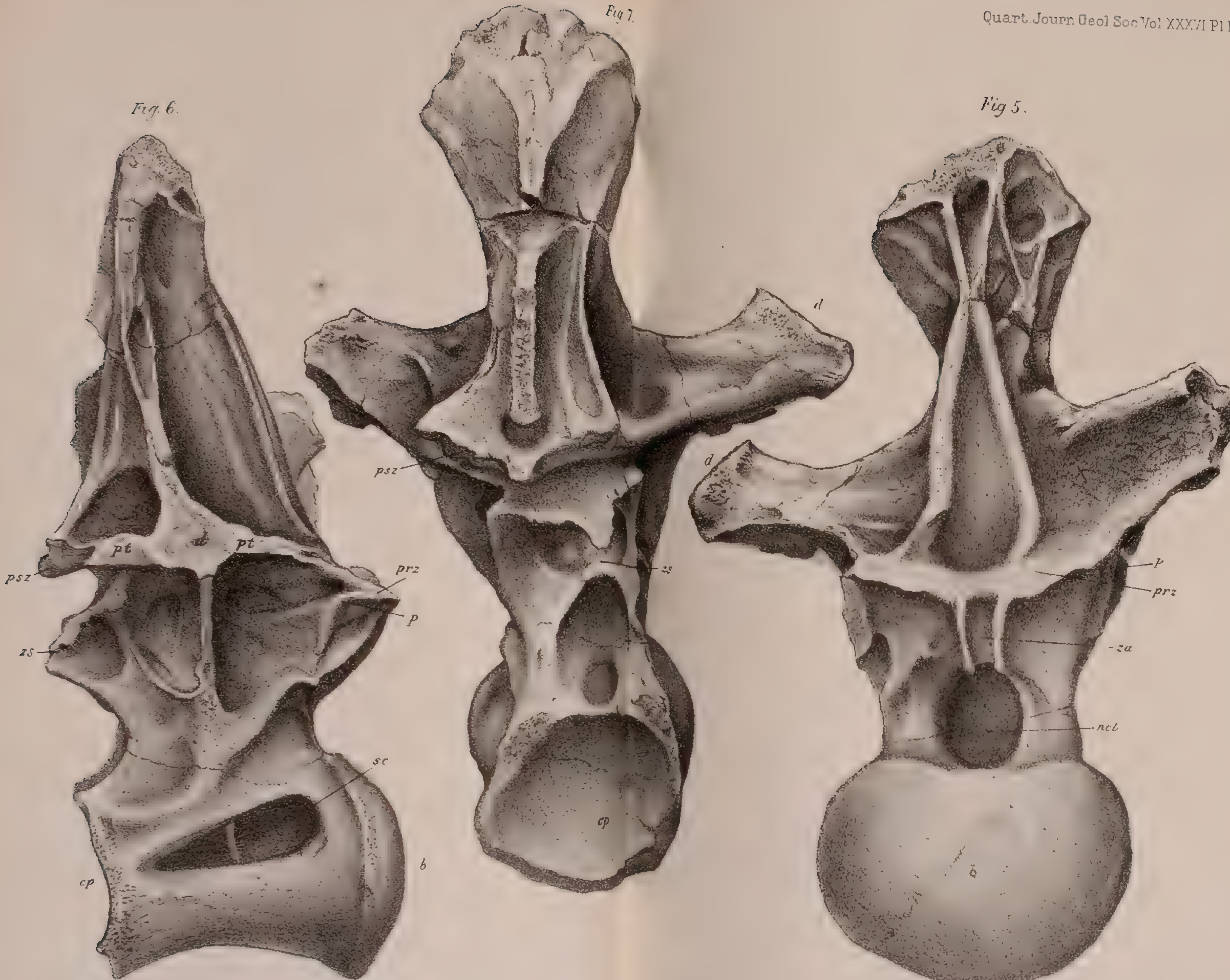
Tail.—All the vertebræ yet discovered which I can confidently refer to the animal belong to the neck and trunk. I know of none which bear chevron facets or other marks whereby to assign them to the tail, a circumstance which is not without significance when we consider the large number of vertebræ in most reptilian tails. May its caudal vertebræ be, like those described in certain of the new American forms, unchambered and relatively solid? In the same Wealden beds which have yielded these cervical and dorsal vertebræ caudal vertebræ not unfrequently occur. Of these, the most common are those laterally flattened forms which are correctly assigned to *Iguanodon*. Next in frequency are two types which have usually been given to *Ceteosauri*. Of these, one I have good reason to place in the tail of *Iguanodon* immediately behind the spot where the transverse process disappears. The other, which often attains much larger dimensions than in *Iguanodon*, is also relatively shorter and of coarser texture. May these belong to *Eucamerotus*? Not long since I should have rejected this conjecture as unworthy of attention; but the late Colorado discoveries show that it would not be safe to do so.



C. Berjeau lith

VERTEBRÆ OF ORNITHOPSIS

Hanhart imp



VERTEBRÆ ORNITHOPSIS

Hauhart imp

EXPLANATION OF PLATES III. & IV.

All the figures are about one fourth the natural size.

Fig. 1. Side view of cervical vertebra. (No. II. 4, Mr. Fox's Catal.) (The præzygapophyses, the dia- and parapophysis and a piece of the border of the posterior articular cup have been broken off.)
Fig. 2. Under surface of another cervical vertebra. (No. II. 6, Mr. Fox's Catal.)
Fig. 3. Front view of another cervical vertebra. It is somewhat distorted by pressure, and the left præzygapophysis, dia- and parapophysis have been broken off. (No. II. 3, Mr. Fox's Catal.)
Fig. 4. Side view of the same (postzygapophysis broken off).
Fig. 5. Front view of trunk-vertebra.
Fig. 6. Side view of trunk-vertebra. (The free extremity of the diapophysis is detached.)
Fig. 7. Back view of trunk-vertebra. (No. II. 1, Mr. Fox's Catal.).

In all the figures the letters have the following signification:—

prz, præzygapophysis.
psz, postzygapophysis.
za, zygantrum.
zs, zyposphene.
p, parapophysis.
d, diapophysis.
b, ball.
c, cup.
s.c, side chamber.
n.cl, neural canal.
n.cr, neural crest.
pt, side pit.
r, riblet.

Discussion.

Prof. Seeley supported the view of the pneumatic character of the vertebral cavities in this genus by reference to the Chelonians and Birds, and believed that the tissue of the dorsal vertebræ had been excavated and absorbed owing to the pressure of an air-sac upon the vertebræ, due to a sacculate condition of the lungs. He pointed out the value of the new evidence obtained with regard to the neural arch; and (if we may accept the evidence of the American genera as to the carpus and tarsals) we seem to have proofs in these animals of the existence of a suborder of Dinosaurs in which peculiar skeletal modifications are associated with a pneumatic skeleton.

Dr. Meryon took exception to the explanation given by Prof. Seeley as to the absorption of portions of the vertebræ. He suggested that the analogies were with the Sharks and Rays rather than with Birds.

Mr. Hulke replied to Dr. Meryon that while the cervical vertebræ indicate great mobility, the dorsal vertebræ are very firmly locked together. Against the view that the parallel of the singular chambered structure was to be found in the Sharks and Rays, he pointed out that this structure is, in *Ornithopsis*, confined to the dorsal region, and does not extend through the whole length of the vertebral column, as is the case with cartilaginous fishes.

5. *On some undescribed* COMATULÆ *from the* BRITISH SECONDARY ROCKS. By P. HERBERT CARPENTER, M.A., Assistant Master at Eton College. (Read December 3, 1879).

(Communicated by Prof. P. M. Duncan, F.R.S., F.G.S., &c.)

[PLATE V.]

MY work on the *Comatulæ* of the 'Challenger' Expedition naturally led me to a consideration of their fossil representatives; and I found that although continental palæontologists have described several species from the Jurassic and Cretaceous rocks of Central Europe, hardly one has been recorded as occurring in the corresponding formations of the British area. It soon appeared, however, that this is not because we have none to record, but merely because neither descriptions nor names have been given for those which we have. In the following pages I propose to make good this deficiency; but I would first express my sincere thanks to Mr. Etheridge, of the Royal School of Mines, to Professor Hughes, of Cambridge, and to Messrs. Henry Woodward and R. Etheridge, jun., of the British Museum, for the ready kindness with which they have allowed me to make use of specimens in the collections under their charge. I am also greatly indebted to Dr. Wright, of Cheltenham, for placing at my disposal two specimens from his own collection.

Schlüter * has recently published some descriptions, together with excellent figures, of several new fossil *Comatulæ* from Germany, Italy, and Sweden. At the same time he has expressed some views as to their anatomy and classification which are inconsistent with some of his statements of fact, and still more so with the results of my own observations on the anatomy of the recent species.

He gives the following general description † of the "Knopf" or centrodorsal piece, which is the part of the skeleton that is most usually found fossil, frequently being the only part preserved:—

"Besides the central pit lodging the heart or chambered organ . . . . . . many species have five other smaller pits, disposed radially around the central one. These radial pits, as shown by Greeff for *Antedon europæus* (*Comatula mediterranea*) and by Ludwig for *A. rosaceus*, are blind saccular extensions of the body-cavity, which penetrate into the apical skeleton, but contain no special organs in the mature animal. In several (fossil) species there is a stellate depression on the underside of the centrodorsal. Each ray of this star corresponds with one of the radial pits, which become narrower from above downwards. The inner part of the star is filled up with calcareous deposit, as a consequence of which the radial pits are also closed below."

There are several points to be noticed in the above description. In the first place, Schlüter is hardly correct in saying that "many species" have radial pits. It is true that they occur in six out of the eleven fossil species mentioned by him (including *Glenotremites*

* "Ueber einige astylide Crinoiden," Zeitschr. der deutschen geolog. Gesellsch. Jahrgang 1878, pp. 28–66, Taf. i.–iv.

† *Op. cit.* p. 33.

paradoxus, Goldf.), but they are wanting in three others (including *G. conoideus*), while we know nothing as to their presence or absence in the two remaining species, since their centrodorsal pieces have not been found detached from the radials. They occur in the three Tertiary species described by Edward Forbes *; while Quenstedt † describes them in *Solanocrinus scrobiculatus*, though Schlüter could not find them in his own specimen of this species. I have met with them, or their equivalents, in three fossil species that I shall describe further on, though not in a fourth. With respect to fossil *Comatulæ*, therefore, there is some ground for Schlüter's statement; but this is far from being the case for the recent forms. I have dissected the calyx of thirty species, but have only found radial pits in three of them. In at least two of these, viz. *Ant. rosacea* (=*A. europæus*, Greeff) and *Ant. celtica*, their presence is very uncertain, and in the third (a new 'Challenger' species) they are of a very unusual character. On the whole, therefore, they are not so frequent as might be inferred from Schlüter's description, only occurring in sixteen out of forty-seven species which have been examined as to this point. Then, again, these pits are not exactly blind saccular extensions of the body-cavity, but merely the closed and slightly expanded ends of the canals which are enclosed between the spout-like processes of the rosette and the axial furrows on the inner faces of the radials ‡. These axial canals are directly continuous with the ventral furrows of the skeleton which lodge the dorsal portions of the cœliac canals (parts of the body-cavity, it is true) of the rays and arms; and if their dorsal ends are not filled up by calcareous tissue, as is usually the case in recent *Comatulæ*, they appear as five openings near the centre of the under surface of the radial pentagon. In any case, however, these openings of the axial canals are closed by the ventral surface of the centrodorsal piece on which the radials rest; and this surface is sometimes, but rarely, marked by the five radial pits corresponding to the openings (Pl. V. figs. 5 *a*, 8 *a*).

The last sentence in the passage from Schlüter's paper which is quoted above seems to imply that were the calcareous tissue removed which fills up the dorsal star (of fossil *Comatulæ*) internally, the radial pits would be complete perforations through the centrodorsal piece. I cannot quite make out whether Schlüter believes that this was ever really the case. If it were so (and I think it was so in *Ant. paradoxa*), then the canalicular extensions of the cœlom which end blindly in these pits (or sooner) must have been continued down the larval stem outside the vascular axis; for this axis, as Schlüter himself points out, contained five vessels which expanded

* "Echinodermata of the British Tertiary Deposits," Palæontogr. Soc. 1852, pp. 19, 20.

† 'Petrefactenkunde Deutschlands,' Band iv. "Echinodermen," p. 179, Taf. 96. fig. 57.

‡ See "On the Genus *Actinometra*," Trans. Linn. Soc. 2nd ser. Zoology, vol. ii. pp. 77, 78, pls. 4–6, *q*, Q, & pl. 8. fig. 3, *a.r.c*, *a.i.c*; and also H. Ludwig's "Beiträge zur Anatomie der Crinoideen," Zeitschr. f. wiss. Zool. Bd. 28, Taf. xix. fig. 74, *Lr*, *Li*.

within the centrodorsal piece into the chambers of the so-called "heart." They cannot therefore have entered the lower open ends of the radial pits, which usually lie altogether outside the centrodorsal cavity (see Schlüter's description of them in *Ant. Retzii*, p. 44); but they must have entered this cavity by the more central part of the dorsal star, leaving the outer ends of its rays to the radial extensions of the cœlom. This condition may possibly have existed in such forms as *Ant. semiglobosa* and *Ant. Retzii*, which seem to have retained their stem till a very late period of growth, like the recent *Ant. Sarsii*, as there is a very large dorsal star.

But other fossil species, such as *Ant. lettensis* and *Solanocrinus scrobiculatus*, resemble recent *Comatulæ* in retaining no permanent traces of the attachment of a stem. We may conclude from this that the separation from their stem took place at an earlier period of development than in the case of *A. Retzii*, &c. For such forms as these Schlüter's statement does not hold good; the closure of their radial pits below does not result from the obliteration of the original dorsal star. Thus in *Ant. rosacea* this star disappears at a very early period of growth, long before either it or the centrodorsal piece itself reaches any thing like the size that they have in *A. semiglobosa*, *A. Retzii*, or *A. paradoxa*. This is well seen in pl. xli. fig 2 of Dr. Carpenter's memoir* on this type. The dorsal star is a minute opening in the floor of the wide basin-like cavity of the immature centrodorsal piece, the side walls of which bend inwards very slightly at the points where the radial pits would subsequently appear. The calcareous tissue which closes the dorsal star in the centre of the floor of this cavity must therefore be entirely distinct from that underneath the later-developed radial pits, which is a part of its side walls. Were this absorbed, and the pits thereby rendered sufficiently deep to perforate the lower surface of the centrodorsal, they would do so between the ends of the rays of the dorsal star (supposing it to persist) and the circumference of the plate; and the union of such openings with the rays would give the appearance of a relatively large star, just as in *A. semiglobosa.* There are other fossil species, such as *Ant. sulcata* and *Act. Mülleri* (Pl. V. fig. 6), which resemble most recent *Comatulæ* in having neither radial pits nor dorsal star on the centrodorsal piece.

Schlüter's description of *Ant. lenticularis* contains the following passage (p. 46):—"The dorsal pole is slightly concave and shows a small distinct star, which indicates the presence of radial pits on the upper surface of the centrodorsal." On p. 48 he points out that there is no dorsal star in *Ant. italica*, but only a simple round hole. "The nutritive canal of the stem was therefore not lobate, as in *A. lenticularis*, but round, which also points to the absence of radial pits."

The last sentence refers to the shape of the opening in the middle of the upper surface of the centrodorsal piece, which was formerly regarded as the mouth. It surrounds the upper ends of the chambers of the so-called "heart," which occupies the central

* Phil. Trans. 1866, vol. 156.

cavity of the piece or the "heart-pit" (Schlüter), the "nutritive canal" of Goldfuss and Geinitz*. From these chambers there rises up the "axial prolongation" (Dr. Carpenter) or "dorso-ventral vascular axis" (Ludwig) on its way to enter the visceral mass and to join the oral vascular ring. The above-mentioned opening may therefore be termed the "axial opening."

Now I entirely fail to see why the presence of a simple round hole on the under surface of the centrodorsal of *A. italica*, instead of the ordinary stellate perforation, should determine the roundness of the upper axial opening. In the first place, the expanded cavity (nutritive canal) lodging the chambered organ is not necessarily lobate, like the perforation in its floor; and, secondly, the shape of the axial opening is not necessarily that of the nutritive canal into which it leads. Thus in *A. rosacea* the centrodorsal cavity has a rounded pentagonal or decagonal shape, but its upper opening is frequently constricted and rendered lobate (more so than in any fossil species) by the five projections of its lip that lodge the radial pits. Further, even if there be a round axial opening in *A. italica*, it does not necessarily follow that the radial pits are absent as Schlüter supposes. Neither does the presence of a stellate opening (now closed internally) on the lower surface of the centrodorsal of *A. lenticularis* necessarily involve the presence of radial pits on its upper surface. In the latter case Schlüter's argument would seem to be as follows:—

1. Because there was a stellate dorsal opening there was a "lobate nutritive canal" (ventral).

2. Because there was a "lobate nutritive canal" there were radial pits around its border.

The first proposition is parallel to that already considered with reference to *A. italica*, like which it does not appear to me to be necessarily true. The chief difficulty which I feel about accepting it is the great variability in the shape of the axial opening of *A. rosacea* and *A. celtica*, which may be circular, pentagonal, decagonal, as in *Ant. essenensis* and *Ant. tourtiæ*†, or more markedly 5-lobed. The stellate dorsal opening of these forms is obliterated so very early, that it would be hardly fair to base any argument upon its shape. But in *Glenotremites* (*Antedon*) *paradoxus* the stellate dorsal opening persisted through life as in some other fossil species. We do not find, however, that there was always an axial opening of corresponding shape. Thus in one of the specimens figured by

* Neither of these names is a good one. The latter is a relic of the days of Miller and Goldfuss, when the stem was believed to contain a prolongation of the alimentary canal; while the former is based on the erroneous idea that the chambered organ is a heart. The second name is at any rate the more preferable of the two; for the stem does enclose a vascular axis proceeding downwards from the chambered organ, which is an important part of the blood-vascular system.

† The terms decagonal, lobate, and five-lobed appear to be used indifferently by Schlüter. Thus he places *A. tourtiæ*, which he describes as having a decagonal opening, in the group "*Comatulæ* with radial pits and a five-lobed opening."

Goldfuss (Taf. li. fig. 1) it is decagonal, almost what Schlüter would call lobate; in the other (Taf. xlix. fig. 9*c*) it is only pentagonal; so that in fossil as well as in recent *Comatulæ* the shape of the axial opening was not constant. I do not think, therefore, that any correlation can be established for *A. lenticularis*, any more than for *A. italica*, between the shapes of the two openings, dorsal and ventral, in the axis of the centrodorsal piece.

What I take to be the second part of Schlüter's argument seems even more unsatisfactory than the first; for although in recent *Comatulæ* a lobate axial opening generally does have radial pits around its border, yet this is not always the case, and the pits may occur round a pentagonal opening, as in the fossil *A. paradoxa*, while Schlüter himself records that they may be sometimes present and sometimes absent in *Solanocrinus scrobiculatus*, just as I have found to be the case in *A. rosacea* and *A. celtica*. The occurrence of such variations as these tells strongly against Schlüter's proposed classification of the fossil *Comatulæ*. He divides them into two groups according as they have (A) radial pits and a 5-lobed axial opening, or (B) no radial pits and an undivided opening. Were recent *Comatulæ* classified thus, *A. rosacea* and *A. celtica* would appear in both groups, while some individuals with lobate or decagonal openings but no pits, would find a place in neither!

Although not constant in their occurrence, the radial pits of these two species are peculiar to them among all the recent *Comatulæ* I have examined. In no other species have I found any thing exactly like them. They are not parts of the generally concave surface of each radial area, but have distinct peripheral borders *, marking them off from these surfaces. They have a precisely similar appearance in *Ant. rotunda* (Pl. V. fig. 5*a*), except that they are a trifle deeper and more distinct than in *A. rosacea*; but they have nothing like the relative size of the radial pits in most of Schlüter's species. Besides *A. rosacea* and *A. celtica*, I only know of one other recent *Comatula* in which radial pits occur; but their shape is very peculiar. The axial opening is bluntly lobate, and the pits are situate at five points on its projecting lip, or, rather, their central ends are; for they bifurcate and extend outwards so as to occupy the best part of each radial area, ending a little inside its margin. This feature is of some interest; for in one of Goldfuss's two figures of *A. paradoxa* (Taf. xlix. fig. 9*c*) all the radial pits show a tendency to bifurcation at their outer ends, two of them especially so. The same is the case in our English example of this species (Pl. V. fig. 1) and in *Act. abnormis* (Pl. V. fig. 8*a*).

I have shown elsewhere † that, omitting the little-known *Comaster* of Goldfuss ‡, the recent *Comatulæ* may be referred to three well-marked generic types, viz. *Antedon*, *Actinometra*, and *Promachocrinus*. Lovén's *Phanogenia* is, I believe, only an aberrant *Actino-*

* "*Actinometra*," pl. 4. fig. 15, *q*.

† "Preliminary Report upon the *Comatulæ* of the 'Challenger' Expedition," Proc. Roy. Soc. No. 194, 1879, p. 385.

‡ Journ. Linn. Soc., Zoology, vol. xiii. pp. 454–456.

metra, while I do not think that Semper's *Ophiocrinus*, with only five arms, can be regarded as more than a subgenus of *Antedon*, with which it is similar in all respects, excepting the absence of division in its rays*. The same variation occurs in the ten-rayed *Promachocrinus*, one species having twenty arms and others but ten, as the rays do not divide. The characters of the centrodorsal piece and calyx of *Ophiocrinus* are essentially those of an *Antedon*, with which type it also agrees in the central position of its mouth and the absence of a terminal comb on the oral pinnules †.

Actinometra differs from *Antedon* in several important characters. The mouth is excentric, the ambulacra unequal, and the oral pinnules provided with a terminal comb. These are not characters, however, which could be of any palæontological value; but many such are to be found in the peculiarities of its calyx. I have already referred to this subject elsewhere ‡, though not systematically enough for palæontological purposes. The following descriptions of the centrodorsal piece and calyx of *Antedon* and *Actinometra* are based upon a personal examination of the external characters of over 200 species of recent *Comatulæ*, and upon close comparison of the dissected calices of eighteen species of *Antedon* and eleven of *Actinometra*. I trust, therefore, that they may be regarded as having some systematic value.

The centrodorsal piece of *Antedon* is extremely variable in its appearance. It may have the shape of a shallow basin or a hemisphere, either complete or flattened at the pole; or it may be conical either perfectly so or more or less truncated; or, lastly, it may be more or less distinctly columnar. Occasionally it is a thick disk, almost thick enough to be called columnar, with well-marked upright sides, to which the cirrhus-sockets are limited, the whole (or nearly the whole) of the dorsal surface being free from them. This is the case, for example, in *A. brasiliensis* and *A. macrocnema*.

As a rule, there are at least two and, generally, three or more rows of cirrhus-sockets, alternating in some species (Pl. V. figs. 4, 5), but vertically above one another in others; while though there may be a large central space free from them, it nearly always shows traces of partially obliterated sockets, which are rarely found in this position in *Actinometra* (Pl. V. figs. 6, 8).

The outer faces of the radials of *Antedon* are always much inclined to the vertical axis of the calyx (Pl. V. fig. 4). They are usually much wider at their dorsal than at their ventral ends, having a

* Schlüter (p. 40) seems to be sceptical about *Ophiocrinus* with its "quite undivided arms which are said to start directly from the centrodorsal, a fact that rather wants a closer examination." As all the recent examples of this type which are known to science (including Semper's original specimen) are in my hands at present, I can speak positively as to its characters. De Loriol's discovery of a fossil species in the Urgonian of Switzerland (Denkschr. d. allg. schweiz. Gesellsch. f. d. ges. Naturw. Bd. 23, Zurich, 1869, pp. 57–59) is of considerable interest.

† In one of the 'Challenger' *Antedons* only four rays divide out of the five, the fifth remaining simple and undivided, as is the case with *all* the rays of *Ophiocrinus*. This is a strong argument against the separation of *Ophiocrinus* from *Antedon* as a distinct generic type.

‡ "*Actinometra*," *op. cit.* pp. 61, 76, 81–84.

trapezoidal form; and the opening of the central funnel which is bounded by their upper edges is very narrow, their ventral surfaces being very small and having a steep inward slope. Hence when the calyx is viewed from above (Pl. V. fig. 4 *a*) the greater part or even the whole of these inclined external faces is visible, always down to the opening of the central canal in the transverse articular ridge, and sometimes even the dorsal fossæ for the attachment of the elastic ligament. Most *Antedons* have large muscle-plates, which greatly increase the height of the distal faces of the radials. In most species they are simply continuations of the general straight line of each face; but in a few cases (*A. celtica*, *A. Eschrichtii*, and a few others) they are set on at an angle to the dorsal half of the face, and stand up vertically around the opening of the central funnel. The muscular fossæ lodged in these plates are separated from those for the attachment of the interarticular ligaments by ridges which start from the raised rim around the opening of the central canal, and usually run more or less obliquely outwards to meet the sides of the radials. They are occasionally somewhat curved upwards, as in *A. Eschrichtii*, and still more so in some specimens of *A. brasiliensis* and *A. rosacea* (compare fig. 1 A, on pl. xxxvi. of Dr. Carpenter's memoir, with pl. iv. fig. 14 of my memoir on *Actinometra*); while in one 'Challenger' species (from Station 212) they run almost vertically upwards for some little distance, and then curve outwards, so that the size of the muscular fossæ above them is considerably reduced. The two muscular fossæ on each articular face are either separated by a strong vertical ridge, which ends below in the prominent triangular rim around the opening of the central canal, as in *A. celtica*, *A. Eschrichtii*, and *A. æquimarginata* (Pl. V. fig. 4), or more rarely, *A. rosacea* and *A. prisca* (Pl. V. fig. 7), there is a narrow intermuscular furrow, which dies out below as it approaches the above-mentioned rim.

As with the centrodorsal, so with the radials of *A. brasiliensis* and *A. macrocnema*, which differ slightly from those of other *Antedons* in the following points. There is much less difference than usual between the width of the upper and lower ends of the distal faces, which are comparatively low, so that their long axes are horizontal, and not vertical, as is usually the case. Consequently the centre of the upper surface of the calyx (especially in *A. macrocnema*) is occupied by a wide funnel, the walls of which are formed by the ventral surfaces of the radials.

A. brasiliensis has fairly large muscle-plates; but they are quite small in *A. macrocnema*, and the ridges separating the muscle- and ligament-fossæ are so slightly oblique as to be almost horizontal, though their origin from the prominent and large rim of the central canal is very marked. In each case, however, the general appearance of the calyx is much more that of the *Antedon* than of the *Actinometra* type.

The centrodorsal of *Actinometra* (Pl. V. figs. 6, 8, and fig. in p. 51) is nearly always (so far as my knowledge goes) a low flattened pentagonal disk with one or occasionally two rows of cirrhus-sockets on its sloping sides, while the whole of its dorsal surface is smooth, without any traces of sockets. Occasionally, however, the centrodorsal is rather more convex, and only its flattened apex is free from cirrhi, though this occupies a relatively larger area than in most *Antedons*. The distal faces of the radials are nearly or quite parallel to the vertical axis of the calyx, and also nearly or quite as wide at their upper as at their lower ends. The ventral faces, which in *Antedon* have a steep inward slope, are almost horizontal in *Actinometra*, sloping very gently inwards towards the central space. Hence the opening of the funnel becomes widely expanded, and, when the radial pentagon is viewed from above, little or nothing is seen besides the proper ventral faces of its component radials. All the species of *Actinometra* which I have examined have smaller muscle-plates than those of any *Antedon* except *A. macrocnema*, so that the distal faces of the radials are very low and the muscular fossæ quite inconspicuous. They are separated from the ligament-fossæ by very prominent ridges, which are either horizontal or curved slightly upwards. These start from the sides of the radial, run inwards towards the middle line, and then turn downwards so as to leave between them a wide furrow which gradually dies away below, with the disappearance of its bounding ridges. The only *Antedon* I know which presents features at all resembling these is the anomalous 'Challenger' species from Station 212. The arrangement of the ridges is essentially the same as in *Actinometra*, though the shape of the distal faces of the radials is somewhat different. No *Actinometra* has the distinct rim on the ventral side of the opening of the central canal that exists in all *Antedons*, in which the transverse articular ridge rises up round the opening as a prominent triangular rim.

There is one singular type of fossil *Comatulæ*, the Jurassic genus *Solanocrinus*, Goldfuss*, which has been long regarded as distinct from the recent forms, owing to the appearance of basal pieces on the exterior of the calyx. Schlüter† merges *Solanocrinus* in *Antedon*; for he does not regard the difference between the basals of the two types as of generic value. In the first type they are external, while in the second they are concealed and metamorphosed into a rosette, having been relatively large and distinct during an earlier stage of development. On this subject Schlüter remarks:—"I have never yet seen this rosette, as basals are present in all the species which I have examined." Here, of course, he means basals like those of *Solanocrinus*, which appear on the exterior of the calyx between the radials and the centrodorsal. He describes eight new species, five of which are based on the characters of the centrodorsal piece only; and it is therefore only an assumption on his part that "basalia" were present in those five species. At the time Schlüter's paper was written this assumption was perfectly justifiable, in fact the only one which could be made under the circumstances. It was based on the fact that the only *Comatulæ*, besides *Glenotremites*, with interradial grooves on the ventral surface of the centrodorsal

* 'Petrefacta Germaniæ,' i. p. 166. † *Op. cit.* pp. 36, 49.

which were known at that time were the various species of *Solanocrinus**, the so-called *Comaster*† of Lundgren, and the three small centrodorsal pieces described by Edward Forbes‡ from the Coralline Crag. These last, having no calyx attached, proved nothing either way. The same was the case with the isolated centrodorsal piece of *Glenotremites*, the interradial grooves on which were described as "ambulacra" by Goldfuss, and as sockets for the attachment of the arms by Agassiz, Römer, Pictet, and Geinitz. Their real nature as surfaces of attachment for the basals was first made clear by Lundgren§. The so-called *Comaster*, discovered by Schlüter, and first described by Lundgren, has a centrodorsal with all the characters of *Glenotremites*, viz. a more or less distinct dorsal star, and on the ventral surface radial pits separated by interradial grooves. One specimen retaining the calyx attached to the centrodorsal piece resembles *Solanocrinus* in the presence, above the interradial angles of the centrodorsal, of external basals which obviously occupy the interradial grooves on its ventral surface. Here, then, is the real explanation of the "ambulacra" of *Glenotremites*; and Schlüter was naturally entitled to suppose that all the *Comatulæ* described by him with these interradial grooves had corresponding external basals like those of *Comaster* (*Antedon*) *Retzii*, and presumably, therefore, no rosette.

It is noteworthy, however, that in *A. lenticularis* and *A. italica*, two out of the three species with the calyx preserved, Schlüter had some difficulty in detecting the presence of external basals. In the case of *A. lenticularis* he can only describe them as apparently showing themselves in two places, beneath the sutures of the united first radials; while he neither describes nor figures them in *A. italica*, though, since he says they are present in *all* the fossil species examined by him, it is to be supposed that they exist in this one. An analogous case to that of Schlüter's specimen of *A. lenticularis*, viz. basals appearing externally at some of the angles of the calyx, but not at others, will be noticed further on in *A. æquimarginata* (Pl. V. fig. 4).

The variations are perfectly explained by what is now known respecting recent *Comatulæ*. I pointed out in 1877‖ that in some species of *Actinometra* the rosette is connected with five prismatic or cylindrical rods that lie in a stellate series of interradial grooves (the basal grooves) on the ventral surface of the centrodorsal piece. "These five rods, to which, taken together, the author has given the name of the basal star, vary very greatly in the degree of their development, not only in different species, but in different individuals

* Goldfuss, it is true, says nothing about such grooves, but merely speaks of the basals as articulated on "fünf strahlenförmige Erhabenheiten." These interradial elevations were, however, grooved as in recent *Comatulæ*. Quenstedt ('Echinodermen,' p. 173) describes them as "gefurchte Strahlen."

† "Om en *Comaster* och en *Aptychus* från Köpinge," Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar, Stockholm, 1874, No. 3, p. 69.

‡ "Echinodermata of the British Tertiary Deposits," Palæontogr. Soc. 1852, pp. 19, 20.

§ *Op. cit.* p. 65.

‖ Journ. Linn. Soc. *loc. cit.* p. 452.

of the same species, and to some extent also in the same individual. The reason of this is that these rods are not calcifications in a nucleated protoplasmic network like the other pieces of the skeleton, but they are simply formed by a more or less complete deposition of calcareous matter in the five interradial planes around the fibres of connective tissue which effect the synostosis of the centrodorsal piece with the pentagonal base of the calyx." At the same time I drew attention to the striking resemblance between the basal rays of *Actinometra* and the basals of *Solanocrinus*, noting, however, an important point of difference between the two structures, viz. the appearance of the latter on the exterior of the calyx, but the complete concealment of the basal rays, as well as of the rosette, in those four species of *Actinometra* which I had then examined.

During the past two years I have dissected the calices of a considerable number of *Comatulæ* (26 species), and I have found the basal rays to be always present in *Actinometra*, and generally so in *Antedon*, the European species and *Ophiocrinus* being the exceptions. I have also discovered that in some few species, both of *Antedon* and of *Actinometra*, the basal rays *do* appear upon the exterior of the calyx, as in the fossil *Ant. Retzii* and *Ant. semiglobosa*. Had I not known from actual examination that these recent species have a concealed rosette, I should of course have regarded the visible ends of their basal rays as the unmetamorphosed embryonic basals, and as homologous with the similarly placed basals of *Pentacrinus asteria*. This is, in fact, the view which I have expressed with respect to the basals of *Solanocrinus*; but the extraordinary resemblance between the calyx of *Ant. macrocnema*, from Sydney Harbour, and that of *S. costatus* has led me to doubt its truth. The question is one of great interest, but is beyond the limits of this paper. I am giving it my best attention, and hope ere long to arrive at a definite conclusion respecting it. It is sufficient at present to notice that the existence of basal grooves on the centrodorsal does not necessarily imply the presence of external basals and the absence of a rosette, as is supposed by Schlüter. In some species both are present, and in others only the rosette, so that it is comparatively unimportant whether there are external basals or not in *Ant. italica*. I imagine, however, that a rosette is certainly present, as in all recent *Comatulæ*.

I have referred already to the curious differences in the degree of development of the basal rays, not only in the same species, but also in the same individual. These are very marked in some of the new "Challenger" *Comatulæ*, which may have three of the rays reaching the outer surface of the calyx, while the others are invisible externally, as in most recent *Comatulæ*. This is a parallel case to Schlüter's specimen of *Ant. lenticularis*, which has only two visible, and to a new fossil species, *Ant. æquimarginata* (Pl. V. fig. 4 *c*), the unique specimen of which in the British Museum shows the ends of three or, possibly, four of its basal rays on the exterior of the calyx.

I may mention here that these basal rays also appear externally in my single (dissected) specimen of *Promachocrinus kerguelensis*. There are ten radials, five of which, alternating with the others, are separated from the centrodorsal by the small triangular ends of the basal rays. The precise nature of these "interradial radials" puzzles me a good deal, and I prefer for the present to reserve my judgment about them.

Let us now pass on to the *Comatulæ* which I have to describe.

1. Antedon paradoxa *, Goldf. sp. Plate V. fig. 1.

Glenotremites paradoxus, Goldf. Petref. Germaniæ, i. p. 159, Taf. xlix. fig. 9, Taf. li. fig. 1.

Antedon paradoxus, Schlüter, Zeitsch. d. deutsch. geol. Gesellsch. 1878, p. 42.

The Museum of Practical Geology contains two specimens of a Chalk *Comatula* which agrees very closely with *Glenotremites paradoxus* as described by Goldfuss and Schlüter. The centrodorsal is hemispherical, with a deepish hollow at the pole. The bottom of this hollow is occupied by a five-rayed impression, which is far more distinct in the smaller specimen than in the larger. The cirrhus-sockets are in 10 vertical rows, each row consisting of 2–4 sockets more or less alternating with those of adjacent rows. The characters of the sockets, as described by Goldfuss, are rather peculiar. "They are pierced in the centre by an oval hole, which has a slight elevation at each side, and is apparently only absent from a few of the uppermost pits [*i. e.* sockets]. The remaining surface of the pits, as far as their margin, is marked by very fine grooves, which here and there are continuous with those of the adjacent ones." Very similar cirrhus-sockets occur in some of Schlüter's new species, but only in the Cretaceous ones; and even in these the central perforation has not the oval or keyhole-shape that it has in *A. paradoxa*, and another species (*A. rugosa*) from the English Chalk, which I shall describe immediately.

The basal grooves on the ventral surface of the centrodorsal are rather deep, and of an elongated pyriform shape, just as in Goldfuss's smaller figure (Taf. li. fig. 1). Their sides are more or less distinctly plicated, showing traces of very minute ridges and furrows (Pl. V. fig. 1), which run somewhat obliquely to the axis of the grooves, and give them exactly the appearance represented in Goldfuss's figure. This, I believe, is the real nature of the "paarweise gegenüberstehende Poren" which Goldfuss imagined himself to have discovered, so that he was led to describe the grooves as "Felder der Fühlergänge."

I regard these markings as rather more characteristic of this species and its allies than Schlüter seems inclined to admit. He says "there are, it is true, some irregular punctate impressions in the original specimen, but they are not perforations. They are unimportant and accidental, and have nothing whatever to do with ambulacral pores." Similar markings occur more or less distinctly

* Schlüter uses *Antedon* as a masculine name. I have given reasons elsewhere ("*Actinometra*," p. 16) for preferring to follow Pourtales, who makes it feminine. The latter course seems to be the more correct from an etymological point of view ('Nature,' vol. xv. p. 366).

in *A. rugosa* (Pl. V. fig. 2 *a*); but nothing of the kind appears in Goldfuss's larger figure of *A. paradoxa* (Taf. xlix. fig. 9), the margins of the basal grooves being quite simple and not plaited at all. I imagine that this difference is merely one depending on the state of preservation of the specimen; for in the English examples the plaiting is much more distinct at the sides of some grooves than at the sides of others which are evidently more worn.

The same is probably the case with regard to the differences between the English and German specimens in the nature of the openings on the upper surface of the centrodorsal. The central axial opening in the latter, the so-called mouth, is distinct from the five large oval holes disposed around it, the so-called "genital openings." In the English specimen there is a five-pointed axial opening, the points of which, rather less deep than the centre, seem to correspond to the "genital openings" of Goldfuss's specimens. This is probably due to accident, just as supposed by Geinitz * for his specimens, the "hufeisenförmig erhabene Leiste," which Goldfuss described as forming the central boundary of the pits, having been broken in the removal of the matrix; for the central ends of some of the radial extensions of the axial opening have small projections from their sides, which look as if they were the remains of broken bars bridging these extensions. I say "bridging," because I do not think that these bars were the upper ends of very thin walls separating the radial pits from the central cavity, as in *A. Retzii*. From the condition of the specimen I should rather judge that there was but one five-rayed cavity, and that the central ends of the rays were bridged over by thin bony bars. The outer ends of some of them have a tendency to bifurcation. This was also visible in Goldfuss's specimens, as is well seen in his fig. 9 *c* on Taf. xlix. It is a peculiarity of some interest, because, as already mentioned, it is exhibited in a much more marked degree by one of the 'Challenger' *Antedons*.

But the most curious feature in *A. paradoxa* is its possessing certain characters which are confined, with only one exception, so far as I know, to two *Antedons* inhabiting respectively the northern and southern extremities of the Atlantic. The one is the well-known *A. Eschrichtii* of the Arctic Ocean and the north temperate zone, and the other is a closely allied but not identical form from the Southern Sea (Heard Island). In both of these species the centrodorsal cavity is rather deep, and its walls are marked by strong ribs, the lower ends of which are more or less distinctly visible through the axial opening, projecting beneath its lip which their upper ends help to support. Five of them, those at the inter-radial angles, are often considerably larger than the rest, and may be the only ones visible †. In other cases, however, both these and numerous smaller intermediate ribs are visible through the axial opening, as is seen in Pl. V. fig. 3. The ribs are much more

* "Das Elbthalgebirge in Sachsen," Palæontographica, vol. xv. pp. 91, 92, Taf. xxiii. figs. 8–10.

† Trans. Linn. Soc. ser. 2, Zool. vol. ii. pl. iv. fig. 11.

distinct in some specimens than in others, both species exhibiting a great amount of individual variation in this respect. In the Heard-Island specimen represented here, both the radial and the interradial ribs are exceptionally distinct.

The presence of these ribs is very characteristic of the two polar *Antedons*. It does not appear to depend upon the depth of the centrodorsal cavity; for there are no ribs even in the deepest centrodorsal pieces of the northern *A. celtica* or of *A. phalangium* (Mediterranean), though these centrodorsals may be externally higher and internally deeper than those of small examples of *A. Eschrichtii*. The same is the case with regard to the deep centrodorsals of some new *Antedons* from the South Pacific. Only one of these, from Station 170 (630 fathoms), just north of the Kermadec Islands, shows any trace of ribs. There are only ten, five radial and five interradial, and they are so faintly marked that they would readily be overlooked by any one whose attention was not specially directed to them.

Now in Goldfuss's description of *A. paradoxa* (p. 159) the following passage occurs:—

"The mouth is furnished with five blunt processes, only one of which is preserved in the specimen figured; so that the points of attachment of the rest are visible." According to Schlüter *, however, "the tooth-like process described by Goldfuss in the mouth is nothing but a fragment of the calcareous matrix which has by chance adhered to the specimen at this point." It will be understood that the term "mouth" is here used to mean the central opening on the ventral surface of the centrodorsal.

Schlüter has examined the original specimen figured by Goldfuss, and therefore speaks with authority; but I cannot help suspecting that the interradial process in question was of the same nature as the larger ribs of *A. Eschrichtii* and of its southern representative (Pl. V. fig. 3). In the English specimen which I am describing these interradial ribs are rather prominent; they stand out like buttresses, projecting into the central cavity from the inner ends of the basal grooves which they support; while there are traces of smaller intervening ribs on the end walls of the radial extensions of the central cavity—faint ones, it is true, in four cases, but tolerably distinct in the fifth. It is the presence of these ribs which leads me to think (as pointed out above) that the radial extensions of the central cavity were continuous with it beneath bony bridges, and not cut off from it as in *A. Retzii*; so that they are not precisely equivalent to the radial pits of *A. rosacea* or *A. rotunda* (Pl. V. fig. 5 *a*), which are merely excavations in the projecting lip of the cavity or in the upper surface of its walls.

Diameter of larger specimen, 13 millims.; of smaller, 6 millims. Heights, 7 millims. and 3 millims. respectively.

Locality. Upper Chalk, Dover. Coll. Museum of Practical Geology.

* *Op. cit.* p. 43.

2. Antedon rugosa, n. sp. Plate V. fig. 2.

The centrodorsal is a thick pentagonal disk with rounded angles and steep sides, which bear about twenty-five cirrhus-sockets in two irregular alternating rows. The sockets have keyhole-shaped perforations and striated margins like those of *A. paradoxa*. The dorsal surface is flattened, with a deep central hollow, at the bottom of which is a five-rayed impression. In the centre of the ventral surface is a shallow five-rayed cavity without any ribs on its sides. The rays have straight smooth sides, without any indications of plates or bars separating them from the central space; so that I do not imagine the stellate shape of the cavity to be accidental, as Schlüter * suggests in the case of *A. semiglobosa*. The basal grooves have plaited sides, but are less deep than in *A. paradoxa*; in fact one of them slopes gradually downwards at its central end on to the floor of the central cavity, and is not raised slightly above it, as is the case with the other four. The angles of the ventral surface, where their outer ends lie, project rather prominently (Pl. V. fig. 2, *c*). Beyond the ends of the rays of the central cavity there is a furrow in the middle line of each radial area; its depth is rather variable, for it is sometimes distinct and sometimes barely traceable, *e.g.* the two furrows at the sides of that basal groove which is so much lower than the rest.

Diameter 9·5 millims.; height 3·5 millims.

Locality. Chalk (Sussex). Dixon Collection, British Museum.

Remarks. This species, while resembling *A. paradoxa* in the characters of its cirrhus-sockets and basal grooves, presents many points of difference from that type. It is flatter, with a more pentagonal outline and fewer cirrhus-sockets; while there are no ribs on the walls of the central cavity, the appearance of which is very different from that of Goldfuss's species. The striated cirrhus-sockets, pentagonal outline, and stellate axial cavity (?) are points of resemblance to *A. semiglobosa*; but the latter species has a hemispherical centrodorsal with nearly fifty cirrhus-sockets, and the sides of its basal grooves are not plaited.

3. Antedon æquimarginata, n. sp. Plate V. fig. 4.

This is a well-preserved specimen, consisting of the united radial pentagon and centrodorsal piece. The latter is a truncated hemisphere (9·5 by 3·5 millims.), with a wide but shallow depression in the middle of its under surface, and three incomplete rows of plain cirrhus-sockets, placed more or less vertically above one another, on its sides, seventeen or eighteen sockets in each row. Its ventral surface is a good deal wider than the base of the radial pentagon, the angles of which approach its margin (fig. 4, *a*); but there is a considerable space between the incurved lower border of each radial and the corresponding side of the roughly pentagonal centrodorsal. These spaces gave support to the proximal portions of the second radials, which would thus be partially invisible, the first, of course,

* *Op. cit.* p. 42.

being entirely so, to any one examining the complete skeleton. This concealment of the first radials entirely, and of the second partially, is a peculiar condition which occurs in very few recent *Comatulæ*; but it is common to Schlüter's three species *A. semiglobosa*, *A. lenticularis*, and *A. italica*. In *A. æquimarginata*, as in the first of these, a small portion of the dorsal surface of the radials is visible where it is slightly upturned at their lower angles. At four of the angles (possibly only three) every two radials are separated by a minute triangular piece (fig. 4, *c*) of very variable size, which represents the end of a basal ray. At the other angle, however, and perhaps even in a second (for it is very difficult to decide), this piece is absent altogether, the corresponding basal ray not quite reaching the exterior of the calyx.

The articular faces of the radials (fig. 4, *b*) have nearly all the characters of those of an ordinary *Antedon*. They are trapezoidal in form and rather wider than high, with a considerable inclination to the vertical axis of the calyx, so that almost the whole of them is visible when the calyx is viewed from above (fig. 4, *a*).

The dorsal fossa for the elastic ligament is very large, as in some other fossil *Comatulæ*, and takes up about $\frac{2}{5}$ of the whole height of the articular face. The middle of its upper portion has the usual deep hollow just beneath the great transverse articular ridge. A prominent rim rises from this ridge around the opening of the axial canal, which is thus very nearly in the centre of the articular face. From its upper border there proceed two slanting lateral ridges that separate the large ligamentous from the small muscular fossæ on each side. There is also a prominent intermuscular ridge that proceeds upwards from the same point and reaches the centre of the ventral margin of the articular face; this is not notched, as is usually the case, but quite even, and forms a part of the rim of the deep central funnel.

Height 7 millims.; diameter 9·5 millims.

Locality. The Gault at Folkestone. Original in the British Museum.

Remarks. The characters of this species are intermediate between those of *A. semiglobosa* from the Greensand (=Kreidemergel, Goldf.) of Speldorf and *A. lenticularis* of the Maestricht Chalk. Its resemblance to the latter species lies chiefly in the marked curvature of the sides of the radial pentagon; but it is very like *A. semiglobosa* in the shape of the centrodorsal and the articular faces of the radials, and also in the upturning of the flanks of their dorsal surfaces above the outer ends of the inconspicuous basal rays. The articular faces, however, are less hollowed than in *A. semiglobosa*, so that their opposed edges stand out less prominently than in this species; but these faces have a much more marked inward slope, the dorsal fossa for the elastic ligament being visible to a greater extent, when the calyx is viewed from above, than in either of the two allied species. The relative proportions of the calyx also are different from those which obtain in nearly all the other fossil *Comatulæ*.

4. Actinometra Lovéni, n. sp.

This fossil consists of the centrodorsal, radials, and first two brachials of what must have been a large *Actinometra*. The centrodorsal is exceedingly peculiar, and but for my experience with the 'Challenger' *Comatulæ* I should have been greatly puzzled what to make of it. In fact it has been generally taken for the "head" of a *Pentacrinus*, to which it has a considerable resemblance, except in the absence of external basals; and even these pieces seem to be wanting in some species of the genus (*P. Fisheri* for example) as it is at present constituted.

Actinometra Lovéni, n. sp. From the Gault, Folkestone.

Dorsal aspect of the calyx, showing the clefts between the first radials and the sides of the centrodorsal, which shows no traces of the attachment of cirrhi. × 2.

In my preliminary report upon the 'Challenger' *Comatulæ** I have described how the centrodorsal of some tropical species undergoes a long series of changes in its shape and relations, which do not commence until some time after the loss of the stem and the entry upon a free state of existence. These changes are of three kinds:—(1) the loss of all the cirrhi and the gradual obliteration of their sockets; (2) the lowering of the centrodorsal to the level of the radial pentagon, or sometimes even below it; and (3) the appearance of clefts at its sides between its ventral surface and the dorsal faces of the first radials. These three features are combined in various ways in several tropical *Comatulæ*. The clefts are largest in *Act. stellata*, Ltk., and in Lovén's *Phanogenia typica*; but in the former species the centrodorsal is entirely devoid of cirrhi and altogether below the level of the radial pentagon, while in *Phanogenia* it is a trifle above the level of the radials and bears a few indistinct cirrhus-sockets. *Act. Lovéni* presents a condition intermediate between these two.

* Proc. R. S., No. 194, pp. 390–393.

The centrodorsal bears no trace of cirrhus-sockets, and peripherally is almost, but not quite, on a level with the radials. Its surface rises a little from the periphery towards the centre, and then sinks again. The larger portion of the dorsal surface is thus somewhat concave, and the hollow is partially filled up with pyrites. The radial clefts are very marked, but are chiefly due to the inner edges of the radials being concave instead of straight, as the sides of the centrodorsal are much less curved than in *Phanogenia* or *Act. stellata.* Hence its outline is only very bluntly stellate. The first radials are thus very much shorter in the middle than at the sides along their lines of suture, the inner ends of which are in contact with the points of the centrodorsal star. The distal edges of the first radials are also somewhat incurved and receive the convex proximal edges of the second radials; these, as well as the axillaries, are rather arched from side to side. They are twice as long as the first radials (along their middle line), have a nearly straight distal edge, and are only partly united laterally. The axillaries are broadly pentagonal and about half as long again as the second radials; the first brachials oblong and partly united laterally, the opposed inner faces of each pair having small fossæ which lodged the ligament connecting them. The articulation between them and the second brachials was by ligaments attached on either side of a vertical ridge as in *Ant. rosacea.* The second brachials are bluntly wedge-shaped and rather convex, their distal articular faces having the usual fossæ for muscles and ligaments, and a large pinnule-socket towards the outer side.

Total diameter across the circle of second brachials 21 millims. Diameter of centrodorsal plate 5 millims.

Locality. The Gault of Folkestone. Original in the Woodwardian Museum, Cambridge.

Remarks. The chief interest of this fossil is that it shows the same altered condition of the centrodorsal as we now find in *Actinometræ* from the Philippines and the Malay Archipelago, all of them from quite shallow water, *i. e.* 20 fathoms or less.

I have much pleasure in dedicating this fine species to Prof. Lovén, whose description of *Phanogenia* has helped me greatly towards understanding the peculiar features which it presents.

5. Antedon rotunda, n. sp. Plate V. fig. 5.

Centrodorsal hemispherical, slightly flattened at the pole, which is free from cirrhus-sockets and marked by a shallow stellate impression. Sockets polygonal, closely set in four alternating rows with occasional traces of a fifth and even of a sixth. Ventral surface very slightly concave, with a markedly circular outline, and a faintly lobulated axial opening leading into a shallow central cavity. Basal grooves rather wide, with rounded distal, and bluntly pointed proximal ends. Central ends of radial areas occupied by small shallow pits lying a little way from the margin of the axial opening.

Diameter 4·5 millims.; height 2 millims.

Locality. The Haldon Greensand (Neocomian). Original in the British Museum.

Remarks. The ventral surface (Pl. V. fig. 5, *a*) of this elegant little species has some resemblance both in shape and in appearance to that of *Ant. essenensis*, Schlüter, from the later "Cenomanien." The radial pits, however, are relatively smaller and less distinctly four-sided than in *Ant. essenensis*, and the cirrhus-sockets are considerably more numerous and more closely set.

6. Actinometra abnormis, n. sp. Plate V. fig. 8.

The centrodorsal of this peculiar little species is a thin, irregularly four-sided plate with rounded angles. Its dorsal surface has gently sloping sides, which bear about thirty rather deep cirrhus-sockets in an incomplete double row. Inside the line of sockets the surface is tolerably flat till near the centre, where it rises slightly. On the slope of this central elevation are five somewhat lancet-shaped pits, radial in position and rather variable in size and depth; three of them are partially filled by small rod-like pieces all of different lengths. At the apex of the specimen I found an irregular circular pit nearly filled up by a small tubercle rising somewhat above its edge.

On carefully cleaning away under water with a camel's hair brush the clayey material at the bottom of the internal cavity, I found this tubercle to be the broken end of a tiny rounded rod. This seems to have somehow found its way into the cavity of the centrodorsal, and to have become fixed in its dorsal opening by the hardening of the clayey matrix. The central cavity is rather deep, with nearly vertical walls on which some of the internal openings of the cirrhus-canals are just traceable. Its upper axial opening is irregularly hexagonal with rather rounded angles, the ventral surface of the plate sloping very gradually from its circumference towards the opening, near the margin of which the slope increases a little. On this steeper part are five shallow radial pits of variable shape: two are roughly quadrangular, each with a low radial bar dividing it into two parts; another is distinctly bifurcate, one division being longer than the other; while the two remaining pits are rather indistinct, their distal ends not being very clearly separable from the irregular furrows in the outer parts of the radial areas. The basal grooves, also rather indistinct, are narrow and parallel-sided.

Diameter 4·5 millims.

Locality. The Bradford Clay, Cirencester.

Remarks. The discoidal shape of the centrodorsal and the limitation of the cirrhi to its sloping sides are characteristic of *Actinometra.* The presence of radial pits is unusual, for I have not found them in any recent species of the genus.

The specimen was found by the late Dr. S. P. Woodward and given by him to Dr. Wright of Cheltenham, who has kindly placed it in my hands for description.

7. Antedon prisca, n. sp. Plate V. fig. 7.

Besides the isolated centrodorsal just described (*Act. abnormis*), a second specimen from the same locality, but with the radials attached, was forwarded to me by Dr. Wright; but, to my great regret, it arrived in a most fragmentary condition. The centrodorsal was in several pieces, one or two fortunately being rather large; while the radials were all separated from one another, and one of them broken in two. These, however, I have succeeded in fitting together sufficiently well to be able to see their general characters. Between the lower angles of the contiguous radials there appear externally the rounded ends of small basal rods, just as in the species of *Solanocrinus* from the White Jura of Germany and *Ant. æquimarginata* (Pl. V. fig. 4, *c*). These are possibly the ends of basal rays just as in recent *Comatulæ*; but owing to the condition of the specimen it is impossible to make out whether their central ends were connected with a rosette as in the living species.

The greater part of the dorsal surface of the radials is synosteal for their attachment to the centrodorsal, only a small peripheral portion being turned upwards so as to appear on the exterior of the calyx, where it would be barely visible except just at the angles. There is thus considerably less of an "outer dorsal surface" than in *S. costatus*, which this type resembles in most other points, viz. the basal pieces appearing externally, the slope of the outer faces of the radials and their shape, wide and low with large ligamentous and small muscular fossæ, which are separated by a slight furrow. The latter features are usually characteristic of *Actinometra*, but they also occur in *Ant. macrocnema* and *Ant. brasiliensis*, and are accompanied, as in this fossil, by a greater slope of the distal faces of the radials than I know of in any *Actinometra*. I have carefully compared the radials of this fossil with those of eleven recent species of *Actinometra*; but they have a much less resemblance to any of these than to the radials of *Ant. brasiliensis*, the distal faces of which are also considerably inclined to the vertical axis of the calyx. The large size of the transverse articular ridge and the number of cirrhus-sockets on the larger fragments of the broken centrodorsal piece also point to this fossil being an *Antedon*. Except for having a notch in the middle of their upper border and an intermuscular furrow descending from it, the wide and low distal faces have a general resemblance to those of *Ant. æquimarginata* (Pl. V. fig. 4, *b*, *c*).

Width of a single radial 3 millims.

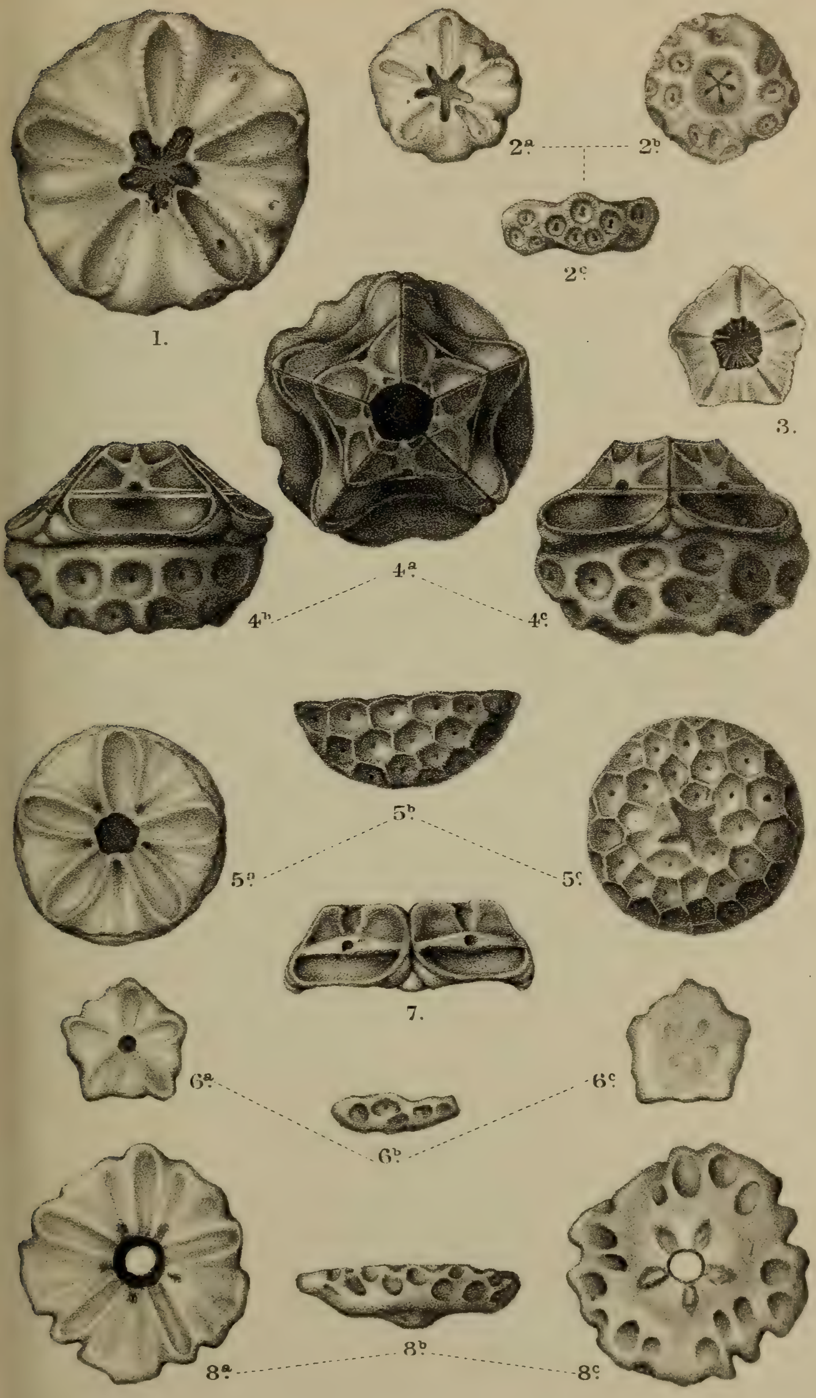
Locality. The Bradford Clay, Cirencester.

Found by Dr. S. P. Woodward; now in the collection of Dr. Wright.

This is the oldest known *Antedon*, no species of *Solanocrinus* occurring in Germany below the lowest beds (α) of the White Jura, which correspond to our Middle Oolites.

8. Actinometra Mülleri, n. sp. Plate V. fig. 6.

Centrodorsal a thin pentagonal disk with from 2–4 sockets along



C. Berjeau del et lith.

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BRITISH SECONDARY COMATULÆ

each side. The largest specimens (5·5 millims.) are the flattest, having the widest cirrhus-free space. In the smaller ones the dorsal surface is more generally convex, and the plate has less distinct sides.

Ventral surface flat, with a round axial opening. Basal grooves shallow, slightly widening from central to distal ends.

Locality. The Great Oolite, Bath.

There are five specimens in the British Museum, one of which is very small, and the others more nearly equal. All are very much worn.

Remarks. This, the earliest known *Comatula,* is a good typical *Actinometra*, so far as can be judged from the appearance of the centrodorsal, which is very similar to that of many recent species from the Philippines and Malay Archipelago. I dedicate it to Johannes Müller, to whom we are indebted for its generic name.

EXPLANATION OF PLATE V.

Fig. 1. *Antedon paradoxa,* from the Upper Chalk, Dover. Ventral surface of centrodorsal. × 3.

2. *Antedon rugosa,* n. sp., from the Chalk. Centrodorsal: *a,* ventral surface; *b,* dorsal surface; *c,* from the side. × 2.

3. Ventral surface of the centrodorsal of a new (recent) *Antedon* from Heard Island. The lower ends of the ribs on the walls of the internal cavity are visible through the axial opening. × 3.

4. *Antedon æquimarginata,* n. sp., from the Gault, Folkestone. Centrodorsal and radial pentagon: *a,* from above; *b,* from the side, radial view; *c,* from the side, interradial view, showing the end of one of the basal rays between the lower angles of two contiguous radials. × 4.

5. *Antedon rotunda,* n. sp., from the Haldon Greensand. Centrodorsal: *a,* ventral surface; *b,* from the side; *c,* dorsal surface.

6. *Actinometra Mülleri,* n. sp., from the Great Oolite, Bath. Centrodorsal: *a,* ventral surface; *b,* from the side; *c,* dorsal surface. × 3.

7. *Antedon prisca,* n. sp., from the Bradford Clay, Cirencester. Side view of two contiguous radials, showing the end of a basal piece between their lower angles. × 6.

8. *Actinometra abnormis,* n. sp., from the Bradford Clay, Cirencester. Centrodorsal: *a,* ventral surface; *b,* from the side; *c,* dorsal surface. × 8.

6. *On the* Fish-remains *found in the* Cannel Coal *in the* Middle Coal-measures *of the* West Riding *of* Yorkshire, *with the* Descriptions *of some* New Species. By James W. Davis, Esq., F.S.A., F.G.S., &c. (Read November 5, 1879.)

In a paper I had the honour to read before this Society in 1876 *, a section of the strata composing the West Riding of Yorkshire Coal-field from the Elland Flag rock to the Blocking Coal is given. The Blocking Coal is probably the equivalent of the Silkstone Coal of the more southern part of the Coal-field, and is regarded by the members of the Geological Survey as the most convenient stratum to form the dividing line between the Lower and Middle Coal-measures. The coal-seams yielding the fossil fish-remains which form the subject of the present paper occur about 400 feet higher in the series than the Blocking Coal. The following section may serve to give an idea of the position of the Stone- or Gas-coal of Adwalton and the surrounding district:—

	ft.	in.
Thornhill rock	120	0
Blue argillaceous shale	16	0
Joan Coal	1	6½
Blue shale	24	0
Coal	0	10
Seat-earth	6	0
Blue shale, with layers of ironstone	13	0
White earth, with bands of ironstone	7	0
Black shale, with *Anthracosiæ*	3	0
Adwalton Stone or Cannel Coal	1	10
Seat-earth	2	0
Strong white stone	17	0
Blue shale	4	0
Black Coal	0	7
White stones with shales	31	0
Forty-yards Coal (Dewsbury Bank Coal, or the Flockton Thin or Adwalton Black bed)	3	0
Seat-earth	3	0
Blue shales, &c	43	0
First Brown Metal Coal	2	0
Strong sandy shale	24	0
Second Brown Metal Coal, or Old Hards	1	10
Seat-earth	3	0
Soft blue shale, with ironstone	10	0
Coal	0	9
Blue shale and ironstone	26	0
Sandstone	20	0
Blue shale	12	0
Middleton Little Coal	2	10
Seat-earth	4	0
Measures with two thin coals	75	0
Middleton Main Coal, Cromwell Coal or New Hards	4	8
Seat-earth with thin layers of coal intercalated	10	0
Measures	35	0
Middleton 11-yards Coal or Three-quarters Coal	2	6½
Measures	40	0
Blocking or Silkstone Coal	3	4

* Quart. Journ. Geol. Soc. 1876, vol. xxxii. p. 332.

The whole series exhibits considerable variations in the character and relative thickness of the strata. The coals, though perhaps more persistent than the other members of the series, do not form an exception. Sections exposed in pits and borings in different localities prove the coals to thin off in certain directions and almost disappear; in some the coal is divided into two bands by lenticular masses of shale or sandstone many feet in thickness; in others two beds of coal gradually converge and form one thicker bed. In this respect the Middle Coal-measures differ from the Lower Coal-measures. The latter, especially in the Lower or Halifax series, are remarkably persistent. The Halifax hard and soft coals extend over the whole of the Coal-field with an almost uniform thickness. They are worked a few miles from Leeds, at Halifax, thence southwards to the Sheffield district, and also in Derbyshire and Nottinghamshire.

The particular bed of coal which has furnished the material for this paper is no exception to the general rule; if any thing, it is more variable than any other coal in the series. The Adwalton Stone Coal or Cannel exists over a district about 20 square miles in extent. It has been, or is, worked at Adwalton, Carlinghow, Bruntcliffe, Gildersome, Morley, Tingley, and Ardsley. On the N.W. and W. the outcrop occurs a little beyond Carlinghow and Adwalton. On the N.E. the measures, including the Cannel Coal, are thrown by a fault against the Lower Coal-measures. On the South and S.E. they gradually thin out and disappear. The following sections serve to show how extremely variable is the quantity or thickness of the Cannel Coal even in this small area.

Taking the colliery at Tingley as a centre, we have the following section:—

	ft.	in.
Black shale with ironstone containing *Anthracosiæ*	0	6
Shell-bed, composed of *Anthracosiæ*	0	9
Black arenaceous shale	1	4
"Hubb" or "Drub" (an impure coal)	1	3
Cannel Coal	1	0
Carbonaceous shale	0	4
Fireclay	1	0

The "Hubb" or "Drub" is an impure Cannel Coal containing a large percentage of earthy matter. It burns with a bright flame, but is rendered useless for making gas by the great quantity of ashes produced during calcination.

At Carlinghow, $2\frac{1}{2}$ miles S.W. from Tingley, there is this section:—

	ft.	in.
Stone Coal	1	3
Coal	0	$2\frac{1}{2}$
Shale and Coal	0	$9\frac{1}{2}$
White earth	0	7
Black Coal	1	0

At Adwalton and Gildersome, at the N.E. extremity, the following section has been exposed:—

	ft.	in.
Black shale (with oil)	0	7
Stone Coal or Cannel	0	9½
Coal	0	11
Dirt	0	3
Coal	0	2
Seat-earth or spavin	0	3
Coal	1	1
Seat-earth	8	0

Between Gildersome and Tingley, in nearly a straight line, about a mile from the latter, is Bruntcliffe, with this section :—

	ft.	in.
"Hubb"	0	2
Stone or Cannel Coal	0	8
Shale parting	0	1
Blendings Coal	0	6
Strong grey shale	0	9
Low-bed Coal	1	4

The Cannel Coal at West Ardsley, one mile south of Tingley, is 6 inches thick, there being a second bed, very impure, 4 inches thick, separated from the former by 7 inches common coal, &c. In the opposite direction, 1½ mile from Tingley, the Cannel Coal has thinned out at Middleton colliery to the following dimensions :—

	ft.	in.
Bituminous shale	0	4
Cannel Coal	0	1½
Common Coal	0	9½
Cannel Coal	0	1
Common Coal	0	2½

At this pit the Cannel Coal has become diminished in thickness to two thin beds 1½ and 1 inch thick respectively, and a little further eastward these finally disappear, their place being supplied by a black bituminous shale. The Cannel Coal has a fine close-grained texture; it is bituminous, and of a dull black colour. It is homogeneous, and breaks with a conchoidal fracture without any trace of the lines of deposition, in this respect differing from common coal. The black bituminous shale, locally named "Hubb" or "Drub," is somewhat similar in appearance to the stone coal, and only differs from it in having a great proportion of earthy matter in its composition. In some instances it contains a quantity of mineral oil, as at Gildersome.

Before enumerating the remains of fossil fish found in the Cannel Coal it may be worth while to consider the circumstances attending the deposition of the coal-seam. The Cannel Coal is thickest in the centre, and thins off in every direction; it becomes less pure, and is replaced by black carbonaceous shales, towards the circumference of the bed. The coals were probably aggregated in a small inland lake, very shallow and liable to be dried up. The plants forming the coal were washed into this lake by streams, and becoming decomposed and settling to the bottom, accumulated in a homogeneous mass, prior to its being changed by pressure and chemical causes into coal. The interlamination of shales, more frequent and thicker nearer the sides of the lake, would naturally result from the mud, also brought down by the streams, settling to the bottom more quickly than the leaves of the plants, but at the same time carrying down with it a large percentage of carbonaceous substances. In some parts the lake appears to have become filled up or elevated above the water-level; and seat-earth filled with Stigmarian rootlets was the result. From the seat-earth grew plants whose remains have formed thin bands of ordinary coal. After the accumulation of the decaying vegetable matter, sometimes deposited in water, and forming Cannel or gas-coal, at others on land, and resulting in thin beds of ordinary coal, the whole was submerged beneath the water, and an average of from one to two feet of black bituminous mud, containing few traces of animal exuviæ, except an occasional layer of Entomostraca, was deposited. Above the black shale there is a light-grey-coloured stratum, about 10 inches to a foot thick, which is almost or entirely composed of the shells of *Anthracosiæ*. Countless numbers of the shells of these mollusks occur; they are always found crushed. They were the shells of animals such as would be found at the present time inhabiting and luxuriating in semistagnant pools—weak and thin, sufficient to serve for the protection of the mollusk in a mass of soft mud in a quiet inland lake, but totally inadequate for its protection if we imagine them to have lived in a flowing river or on the wave-beaten shores of an old sea. Above the shell-bed are about 20 feet of bluish-white shales containing several layers of ironstone nodules. Shells of *Anthracosia* are common in the ironstone, but do not occur in the shale. All these facts point to one issue—that we have in these beds an example of an inland lake of freshwater origin. This is a most important conclusion when we come to consider the variety of fish-remains which have been obtained from these strata.

The fossil fish are found in greatest abundance at Tingley; where the coal has been worked elsewhere, fish-remains are either quite absent or occur with great rarity. At Tingley they are found in largest numbers between the Cannel Coal and "Hubb;" many beautiful examples, however, have been obtained from all parts of the Cannel Coal, and they not unfrequently occur in the "Hubb." The following is a list of the fishes which I have hitherto been able to identify:—

Cœlacanthus lepturus, *Agass.*
Ctenodus elegans (tooth), *H. & A.*
Megalichthys Hibberti, *Agass.*
Rhizodopsis, sp.?
Palæoniscus, sp.?
Gyracanthus formosus, *Agass.*
Ctenacanthus hybodoides, *Egerton.*
Diplodus gibbosus, *Agass.*
Ctenoptychius pectinatus, *Agass.*
Helodus simplex, *Agass.*
Ostracacanthus dilatatus, *Davis* (gen. et sp. nov.).
Compsacanthus triangularis (sp. nov.), *Davis.*
—— major, *Davis* (sp. nov.).
Cladodus-teeth.
Petalodus.
Rhizodus-scales.
Ctenodus, sp.?, ribs and bones.
Pleuracanthus lævissimus, *Agass.*
—— erectus, *Davis.*
—— pulchellus, *Davis.*
—— alternidentatus, *Davis.*
—— alatus, *Davis.*
—— robustus, *Davis.*
—— (Orthacanthus) cylindricus, sp. ined. *Agass.*, *Davis.*
Spirorbis carbonarius.
Entomostraca.
Julus?
Anthracosia (Unio).
Labyrinthodont (?) ribs, teeth, and other bones.

Most of the fishes comprised in this list belong to the Elasmobranchii and Ganoidei; but whereas the Elasmobranchii are generally considered to be of marine origin, and the Ganoids rather to pertain to fresh water, we have them both, in this case, fossil together, and evidently deposited in the immediate neighbourhood of the spot where they lived. The Sharks were of large size; the spines of *Gyracanthus* and *Ctenacanthus* are not uncommon, those of the latter being the largest I have seen from the Yorkshire Coal-field; some of them were quite $3\frac{1}{2}$ inches in diameter near the base. The fossil remains of *Megalichthys* are also of very large size, many of the scales being an inch in diameter, indicating fishes probably five feet in length. Spines of *Pleuracanthus* and *Orthacanthus*, and the teeth and other bones of *Diplodus*, are frequently found. Of the spines several species have been found, and are of such peculiar and varied forms, as to leave little doubt that *Pleuracanthus* and *Orthacanthus* must be united to form one genus, with the *Diplodus*-teeth also added. The remains of these genera are unique in richness, and I propose to deal with them in a separate paper. By far the greatest number of specimens, however, belong to the genus *Cœlacanthus*; the remains of hundreds of these fishes have been obtained from a comparatively small area in the most exquisite state of preservation. *Rhizodopsis* is rare; about half a dozen specimens comprise all found. The teeth of *Ctenoptychius*, *Helodus*, *Cladodus*, and *Petalodus* are also very rare, so are the scales of *Rhizodus* and the teeth of *Ctenodus*. A single tooth of *Ctenodus elegans* with a few head-bones and ribs of a larger species comprise the specimens hitherto found of this genus.

There are two beds of Cannel Coal which in lithological and palæontological characters bear so great a resemblance to the Cannel Coal at Tingley, that it may be advisable to glance briefly at the leading features of each for the sake of comparison with our own beds and their fossils.

In the Report of the Geological Survey of Ohio, Palæontology, vol. i. p. 284, Dr. Newberry describes a bed of Cannel Coal which bears a close resemblance to the one at Tingley. It occurs at Linton, on the Ohio river. At the base of a thick seam of ordinary Coal (no. 6) is a thin bed of Cannel Coal. The Cannel is only local in extent, and on tracing the thick coal in various directions the Cannel is found to disappear. After careful study of the deposit, Dr. Newberry considers "that there was in this locality, at the time when the coal was forming, an open lagoon, densely populated with fishes and salamanders, and that after a time this lagoon was choked up with growing vegetation, and peat (which afterwards changed to cubical coal) succeeded to the carbonaceous mud (now Cannel) that had previously accumulated at the bottom of the water." The species of fish found in this Cannel are about twenty in number, and the amphibians are equally numerous. The fishes consist of nine species of *Eurylepis*, a small tile-scaled Ganoid, two or three species of *Cœlacanthus* (closely allied to *C. lepturus* of the

English Coal-measures), scales and teeth of *Rhizodus,* spines of *Orthacanthus* and *Compsacanthus,* and teeth of *Diplodus.*

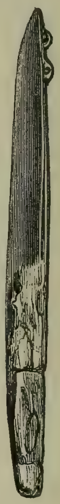
The parallel between the Linton and Tingley beds of Cannel Coal is very remarkable; they are both of an isolated and local character and associated with common coal, they appear to have had a similar origin, and, most peculiarly, they are each the depository of a large number of fossil fishes. I doubt very much if there is any other bed in the British coal-fields which has yielded a greater number of specimens of fish or even a greater number of new species in so small an area as the Cannel at Tingley; and Dr. Newberry remarks of the American beds that, "on the whole, this must be looked upon as one of the most interesting localities of vertebrate fossils known on this continent; and it is even doubtful whether any other equals it in the number of species or in their zoological and geological interest."

The researches of my friend Dr. Anton Fritsch, of Prague, in Bohemia, on the gas-coals of Nyřan and Kounovà, during the past few years, have resulted in the discovery of a remarkably large number of Labyrinthodonts and fishes. The gas- or Cannel Coal of Bohemia is situated much higher in the geological series than the beds at Tingley or Linton. It is only about 30 metres below the red and green clays of the Permian formation; and the gas-coals with the sandstones and shales above them are considered as passage-beds between the Carboniferous and Permian formations. The coal-seam is from a metre to a metre and a half thick, and consists of alternations of ordinary coal, Cannel or gas-coal, shales and clays. About the middle of the bed is a Cannel Coal 30 centimetres thick, and under that are thin slaty shales 25 centimetres in thickness. In the Cannel the remains of fishes or Labyrinthodonts are rarely found, but in the shale beneath they are very abundant. Separated from the shale by a thin bed of clay, there is a thick bed of slaty shale, which contains a thin layer of clay ironstone and also the remains of fishes, &c. The slaty shales beneath the gas-coal appear to be very similar to the "hubb" of the Cannel at Tingley; and it may be worthy of note that it is in these bituminous shales in each instance that the remains occur abundantly. There has been found altogether a fauna of 87 species; of these, 43 are Labyrinthodonts, 33 fishes, and 11 Arthropoda. The fishes occurring in greatest abundance are:—*Ceratodus Barrandei*, Fr. (= *Ctenodus obliquus*, H. & A.); *Orthacanthus bohemicus*, Fr. (= *O. cylindricus*, Ag.); *Xenacanthus* (= *Pleuracanthus*, Ag.). There are thirteen species of *Palæoniscus,* four of *Amblypterus*, two of *Acanthodes*, a *Phyllolepis*, a *Gyrolepis,* and a new genus, *Sphærolepis kounoviensis*, Fr. The remaining eight species are *Ceratodus applanatus*, Fr., two species of *Diplodus*-teeth (?), *Xenacanthus Decheni*, two species of undetermined genera, and *Hybodus* (?) and *Petalodus* (?) The most notable features of the Cannel-Coal series of Bohemia are:—the great number of Labyrinthodonts, most of the species being hitherto unknown; the absence of Elasmobranchs of the type of *Gyracanthus* and *Ctenacanthus*, which in the Tingley beds are of frequent occurrence; and the preponderance of Ganoids of the genera *Palæoniscus, Amblypterus,* and *Acanthodes.* The entire absence of *Cœlacanthus* and *Megalichthys* is also peculiar. The fauna generally is of a Permian type compared with either that of America or Yorkshire; and the supposition that the beds form an unbroken connexion between the Coal-measures and the Permian formation may happily prove correct.

COMPSACANTHUS TRIANGULARIS, sp. nov., Davis. Fig. 1.

Spine. 2·5 inches in length, ·2 inch in diameter at mid length, where it is greatest. The spine on the posterior face is straight; the anterior face is slightly curved. From the centre the diameter becomes gradually smaller in each direction; at the apical extremity it ends in a point; towards the base the spine is thinner and somewhat crushed. The portion which has been implanted in the muscles contracts in size to about three fourths the greatest diameter. There is a large terminal cavity, which passes up the centre of the spine towards the point, becoming smaller, and the walls of the spine proportionately thicker and stronger, as it ascends. The lateral and anterior surfaces are covered with a combination of striations and flutings. The lateral faces are compressed towards the front, which gives a section of the spine a triangular form. The posterior portion is circular; and the apex is armed with two denticles, broad at the base, compressed laterally, and ending in an obtusely rounded point; they are placed one behind the other in a single row.

Fig. 1.—*Compsacanthus triangularis*, sp. nov. Spine, nat. size.



Locality. Cannel Coal, Tingley near Leeds.

The spine described above differs from *C. lævis*, Newb., in several important respects. Instead of there being a series of twenty or thirty denticles on the posterior median line, there are only two, and these are not hooked and acuminate; the spine is shorter and stouter; its section is triangular. It has only one row of teeth; and for this reason it is included in the genus *Compsacanthus*, Newb., with the specific designation *triangularis,* in allusion to its triangular form.

COMPSACANTHUS MAJOR, sp. nov., Davis. Fig. 2.

Spine. Part preserved, 7 inches in length; with the point, which is wanting, the spine would have been about 7·5 inches in length; the breadth is ·55 inch at the base, and thence to the apex it gradually and regularly tapers to a point. It is straight, and its surface is ornamented by a series of longitudinal striations. On the posterior surface there is a single row of denticles, extending from the apex 2 or 2·5 inches towards its base. The denticles are broad at the base along the longitudinal axis, their sides are compressed, and they terminate obtusely; eight of the denticles and intermediate spaces are contained in the space of 1 inch. The spine is somewhat flattened, and presents an oval section; but this is probably due to compression, and the spine may originally have been nearly or quite circular. There is an internal cavity, which is terminal at the basal extremity and extends almost to the point; the cavity is central, and large in comparison to the diameter of the spine.

Many of the Siluroid and Cyprinoid fishes of the fresh waters of India bear on the anterior portion of the first dorsal fin a bony ray or spine, which is frequently ornamented or armed with a row of denticles along its posterior margin. Among the Cyprinoids may be mentioned the *Schizothorax*; and in a species of Siluroid, *Macrones vittatus*, Bl., kindly sent to me by Mr. Francis Day, and collected by that intrepid naturalist in one of the rivers of Northern India, there are one dorsal and two pectoral fins, protected by spines; these present a close external resemblance to the spines of *Compsacanthus* from the Coal-measures of West Yorkshire. The *Macrones* is a small fish, about 5 inches long; its head is covered with a number of bony plates, whilst the body is devoid of scales. It has two pectoral and two ventral fins, and an anterior and posterior dorsal fin. All except the

Fig. 2.—*Compsacanthus major*, sp. nov. Spine, nat. size.

latter are supported by fin-rays. The posterior dorsal is a cartilaginous fin, presenting the appearance and condition of those found in Sharks.

The peculiar characteristic of special interest for our present purpose consists in the presence of the bony spines or fin-defences. The pectoral fins are each armed with a strong spine, the exposed part of which is ·5 inch in length, the diameter being equal to about one tenth of the length. The posterior face of the spine is straight, the anterior slightly curved, tapering to a sharp point; it is somewhat flattened laterally, and ornamented with longitudinal striæ. On the median posterior surface is a single row of denticles, fourteen in number, extending along the whole length of the exposed part of the spine; the denticles are slightly recurved towards the base, pointed, and about equal in length to the diameter of the spine. Attached to and extending behind these spines are the pectoral fins.

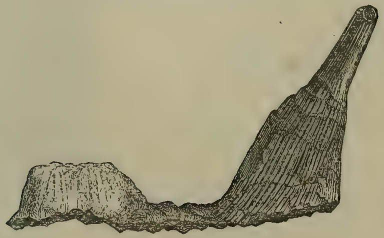
The dorsal spine is about two thirds the size of the pectoral ones. It is straight, pointed, striated longitudinally, and has on its posterior surface a single row of short straight denticles, seven in number; these point towards the base at an angle of 45°. It is not connected with the dorsal fin, but stands alone. It is implanted with a peculiar interlocking joint in a triangular-shaped bone, formed by a prolongation of the bony covering, extending backwards from the occipital region of the head.

These characters present an analogy with the *Compsacanthus*-spines, which appears to indicate a possible relationship between the fossil spines and their modern representatives.

Ostracacanthus dilatatus, gen. et sp. nov., Davis. Fig. 3.

This is a very peculiar form of "Ichthyodorulite" connected with certain other bones which have the appearance of being the exoskeletal plates of a fish. The principal part of this specimen

Fig. 3.—*Ostracacanthus dilatatus*, sp. nov. Spine, nat. size.



consists of a bony protrusion or spine, which is 1·4 inch in length. The base is imperfect; it now measures ·5 inch; had it been perfect, its breadth would probably have been ·7 inch. From the base the diameter diminishes rapidly, and at half an inch from the apex it is ·15 inch. This diameter is maintained for ·4 inch, the spine then terminating abruptly in an obtuse point. The spine may originally have been round; it is now somewhat compressed in form. The upper part is smooth, and covered with hard black ganoine. The lower part is fluted with longitudinal grooves, which increase rapidly in number by bifurcation. The spine appears to be solid; no internal cavity or canal can be distinguished in this specimen. Its base is composed of chondriform bone, *i. e.* cartilage with numerous minute osseous centres, a very similar structure to that of the semiosseous skeleton of *Pleuracanthus*. Extending laterally from the base there is a mass of similar chondriform bone; contiguous to the spine it is produced into two or three short denticles. It then becomes thinner, but again develops into a mass which may very well have served as the base of a second spine, providing one was present (see fig. 3). There is no distinct evidence, however, of a second spine having been present on this specimen; it has rather the appearance of a thick scale, somewhat acuminate towards the centre.

The only fish-remains hitherto described which have any resemblance to these are comprised in the genus *Byssacanthus** of Agassiz. It is defined as containing spines more or less arched, longitudinally furrowed, with the base much expanded. The spines are about an inch in length and three quarters of an inch wide at the base; they converge rapidly to an obtuse point, and are more or less arched; deep grooves extend longitudinally along each lateral expansion reaching quite to the point. In some respects *Byssacanthus* presents features similar to those of the spine described above. Both are obtusely pointed and expanded towards the base; but whilst in *Byssacanthus* the anterior portion of the spine is round and strong, the posterior is much expanded and appears to be very thin. The basal portion in my specimen radiates equally in all directions from the point; the furrows in the latter indicate the homogeneous character of the spine by their similarity in form and arrangement on all sides: in *Byssacanthus* they are very different; on the thick anterior portion the striations are parallel to the anterior margin and about equidistant, but on the posterior wing-like expansion they diverge rapidly towards the base and become wide apart.

The spine in its character and its attachment to the dermal covering of the fish bears a strong resemblance to the spines of the existing Trunk-fish, *Ostracion cornutus*. The Trunk-fish is a small squarely-built fish, protected by a covering of six-sided plates. On its anterior and posterior extremities the dermal covering is produced so as to form four bony spines, broad at the point of insertion, rapidly contracting, thence continuing about the same diameter for a short distance, and ending in a point. The spines of the Trunk-fish are long and slender in proportion to their breadth, being fully three times as long as the diameter of the base. The fossil spine

* Pois. foss. du Vieux Grès Rouge, tab. 33. figs. 11–14 and 15.

is comparatively short and much stronger; but otherwise they are very similar both in form and method of attachment.

Hitherto the fishes found in the Coal-measures have been classed as members of one of the two great groups which formed the fish-fauna characteristic of the Carboniferous age, viz. the Ganoids and the Elasmobranchs. In the genus *Ostracacanthus,* if the diagnosis I have attempted should be substantiated by future discoveries, there is evidence that fishes closely allied to some of the more abnormal forms of the Teleosteans of the present day existed during that period. Prof. Huxley* has expressed the opinion that several of the fishes of the Devonian rocks are closely related to the modern Siluroids. In the structure of the head of *Coccosteus* the general arrangement of the bony exoskeleton much resembles that of the tropical fish *Clarias*; while the peculiar form of the mandibles and the expansion of the bony elements usually considered to be homologous with the coracoid and radius of other fishes, so as to form a large ventral shield, offer many points of resemblance to the Siluroid *Loricaria.* The Devonian *Pterichthys* is also in several ways closely related to the modern Siluroids; and the fossil fish *Cephalaspis* has also certain resemblances to *Callichthys* and *Loricaria.* Prof. Huxley remarks:—"At any rate, I think the *primâ facie* case in favour of the Teleostean nature of *Coccosteus* is so strong that it can no longer be justifiable to rank it among the Ganoids *sans phrase*; but even those who will not allow it to be a Teleostean must attach to it the warning adjunct of *incertæ sedis*"; and, further, "Why should not a few Teleosteans have represented their order among the predominant Ganoids of the Devonian epoch, just as a few Ganoids remain among the predominant Teleosteans of the present day? When it is considered that an ichthyologist might be acquainted with every freshwater and marine fish of Europe, Asia, Southern Africa, S. America, the Indian archipelago, Polynesia, and Australia, and yet know of only one Ganoid, the Sturgeon, a fish so unlike the majority of its congeners that a naturalist might be well acquainted with almost all the fossil Ganoids and yet not recognize a Sturgeon as a member of the group, it will not seem difficult to admit the existence of a Teleostean among the Devonian Ganoids, even though that Teleostean should in some, even important, points differ from those with which we are familiar."

It may be somewhat premature, considering the fragmentary nature of the specimen, to express an opinion that a fish resembling the Teleostean *Ostracion* has been found in the Coal-measures. The spine and its peculiar attachment, however, are totally different from every other form of Ichthyodorulite with which I am conversant, and, providing the evidence on which Prof. Huxley bases the arguments given above is held to be correctly applied, and that the oldest Devonian fishes have many points of similarity and relationship with the Siluroid family of the Teleosteans, the probability of

* Mem. of the Geol. Survey, decade x.

the occurrence of fishes of a somewhat similar type during the succeeding Carboniferous age is rendered at least plausible. To distinguish this specimen, I suggest the generic name *Ostracacanthus**, from the resemblance of the spine to those of the *Ostracion*, and adding the nomen triviale *dilatatus*, in reference to its wide and dilated base.

As already observed, the most abundant fossil fish occurring in this bed of Cannel Coal is the *Cœlacanthus*. The specimens are extremely well preserved, and, as might be expected, they are of various sizes, up to 18 or 20 inches in length. I hope, at some future meeting, to treat at greater length on the characters of this genus. For the present it may be mentioned that the teeth were undoubtedly small and sharply pointed; jaws with the teeth *in situ* have not been found, but specimens are frequently met with in which the alveolar spaces are well shown, extending in a single row along the rami of the jaws. The teeth appear to have been loosely held, and to have fallen away from the jaw when the fleshy parts decayed. The air-bladder is well preserved and seems to possess considerable resemblance to the bony air-bladders of some of the Siluroid fishes of the fresh waters of Northern India.

The most striking features elucidated in the foregoing observations are the decidedly Teleostean *facies* presented by some of the fish. There is an immense assemblage of the remains, considering the small area over which the coal-bed extends; and for the most part they consist of species whose nearest allies amongst living fishes are found in the Teleostean Siluroids and Cyprinoids of the rivers in the mountainous districts of Northern India and in South America. There is a remarkable resemblance in the fossil *Compsacanthus* to many of the species of the *Saccobranchi* and *Macrones*. Sufficient is not yet known of the fossil fish to warrant an opinion as to its internal anatomy, or even to say whether the head had a bony covering similar to that of the recent fish; but if these parts should not be found or identified, it may still be maintained that the scaleless Siluroids and the cartilaginous dorsal fin of *Macrones* are indications of an ancestry which may very well serve as the type of the fish which inhabited the waters existing during the period when the Carboniferous rocks were being accumulated.

* *Ὀστρακον*, a hard shell, and *ἄκανθα*, a thorn.

7. *A* Contribution *to the* Physical History *of the* Cretaceous Flints. By Surgeon-Major Wallich, M.D. (Read December 17, 1879.)

(Communicated by the President.)

Some years ago, whilst endeavouring to clear up the obscure points in the history of the Cretaceous flints, I naturally turned for guiding data to such analyses as were forthcoming of the Chalk and Globigerine ooze of the Atlantic. But the further my inquiries were pursued in this direction, the stronger grew my conviction that no more fallacious test of the percentage of silica originally present in the White Chalk could be resorted to than that of assuming as a standard the percentage it now contains, and hence that any comparison of the calcareous mud with the ancient Chalk, instituted with the view to determine this percentage, must necessarily prove equally fallacious.

This result, however, was only to a certain extent unlooked for, inasmuch as I had long previously suspected, on entirely distinct grounds, that the almost complete absence of silica in the flint-bearing Chalk did not arise from any deficiency in it of that substance whilst it was yet in a plastic state at the bed of the ancient sea, but was due to certain special conditions, which led not only to the continuous elimination of the siliceous material for a time mechanically associated with the calcareous mud, but to its consolidation in the stratified layers alternating with the Chalk, which constitutes by far the most striking and, at first sight, unaccountable feature in this formation.

In directing attention, at the outset of my observations, to the writings of those who have preceded me in this line of inquiry, I am actuated by two considerations, namely, a desire to show how much remains to be done before our knowledge of the Chalk flints can be regarded as even approximately complete, and to leave no ambiguity as to the purport of my own investigations, in so far as they can be regarded as original.

Twenty years ago Mr. Mantell, whilst epitomizing the works of M. d'Archiac, Mr. Bowerbank, and others, described the nodules and veins of flint that are so abundant in the Upper Chalk as having been probably produced by the agency of heated water holding silica in solution. The perfect fluidity of the siliceous matter before its consolidation he considered proved, not only by the sharp moulds and impressions of shells &c. retained by the flints, but also by the presence of numerous organic bodies in the substance of the nodular masses, and the silicified condition of the Sponges and other "Zoophytes" which swarm in some of the Cretaceous strata. The solvent power of superheated water on rocks containing silex might therefore be fully adequate to produce all the phenomena presented by the nodules, dykes, veins, &c. of the Chalk formation; and the chalk flints might possibly, he thought, have originated from the quartz of granitic and other plutonic rocks dissolved in the heated water and erupted into the basin of the Chalk formation.

There are other observers, however (Mr. Mantell goes on to say), who are inclined to believe that the flints in the Chalk, and also in the Portland Oolite and other calcareous deposits, owe their origin to the Sponges, of which such frequent traces are recognizable in connexion with the flint. Mr. Bowerbank, he says, advocates this origin for every kind of flint nodule and vein in the Chalk. But how or why the silex, thus considered as representing the Sponges, should have invested or replaced organic bodies, and the Porifera in particular, Mr. Mantell contended was left wholly unaccounted for. Prof. Ehrenberg, he said, suggested that the flints may be due to the chemical segregation of silex derived from the siliceous remains of *Diatomaceæ*, *Polycystina*, &c.

In 'The Student's Elements of Geology' (the latest of Sir Charles Lyell's works in which the subject of the flints is touched upon)* it is stated that the origin of the layers of flint, whether in the form of nodules or continuous sheets, or in veins or cracks not parallel to the stratification, has always been more difficult to explain than that of the White Chalk. But here, he says, the late deep-sea soundings have suggested a possible source of such mineral matter. According to Dr. Wallich it was ascertained that, while the calcareous *Globigerinæ* had almost exclusive possession of certain tracts of the sea-bottom, they were wholly wanting in others, as between Greenland and Labrador. "But in several of the spaces where the calcareous Rhizopods are wanting, certain microscopic plants called *Diatomaceæ*, the solid parts of which are siliceous, monopolize the ground at a depth of nearly 400 fathoms, or 2400 feet. The large quantities of silex in solution," Sir Charles then proceeds to say, "required for the formation of these plants may probably arise from the disintegration of felspathic rocks. As more than half of their bulk is formed of siliceous earth, they may afford an endless supply of silica to all the great rivers that flow into the ocean. We may imagine that after the lapse of many years, or centuries, changes took place in the direction of the marine currents, favouring at one time in the same area a supply of siliceous, and at another of calcareous matter in excess, giving rise in the one case to a preponderance of *Globigerinæ*, and in the other of *Diatomaceæ*. These last, and certain *Sponges*, may by their decomposition have furnished the silex which, separating from the chalky mud, collected round organic bodies, or formed nodules, or filled shrinkage-cracks"†.

Again, in his 'Principles of Geology,' the same distinguished author says, "The homogeneous character of the White Chalk or upper portion of the great Cretaceous formation throughout a large part of Europe is now (1872) explained by discovering that it is made up exclusively of the remains of the calcareous shells of Foraminifera; *while the siliceous portion has been derived chiefly from plants called Diatoms*"‡.

* 'The Student's Elements of Geology,' 1871, p. 264. † *Op. cit.* p. 265.
‡ Lyell's 'Principles of Geology,' 11th edit. (1872), vol. i. p. 216.

Here, then, we have placed before us the various opinions entertained by geologists down to a very recent date, so far as published researches are concerned. Before proceeding with my task, however, I must, with a view to prevent my argument from becoming in some measure unintelligible, correct a serious, though obviously an unintentional, misconception on Sir Charles Lyell's part as regards the opinions always entertained and repeatedly expressed by me in print on the subject of the *Diatomaceæ*. I allude to the statement, attributed to me, that certain areas of the North Atlantic are "monopolized" by these organisms. So far from this being my opinion, in a correspondence with Sir Charles which took place in January 1870 I stated, in reply to a series of questions he put to me, that I have never swerved from the view that the Diatoms are plants—that my belief is that the whole of the Diatoms met with in the deep-sea deposits have not lived there, but have sunk to the bottom from the surface only after death—and that there is only one group, namely the discoidal, which occurs in such profusion at the surface, not of the North Atlantic, but of the tropical Atlantic and other tropical seas, as to furnish any material contribution of siliceous matter to the deep-sea deposits*.

It will, no doubt, be remembered that in 1869 the opinion was promulgated by two very distinguished biologists that the "calcareous mud of the Atlantic is not merely *a* Chalk formation, but a continuation of *the* Chalk formation; *so that we may be said to be still living in the Cretaceous epoch.*" On the merits of this question I think it right to say I have no intention of expressing an opinion, my aim in pursuing the present inquiry being limited to an endeavour to explain, with a fair show of probability, the singularly unique characters and mode of stratification of the Chalk flints. For aught I have now to adduce on the subject, the battle of the epochs will therefore have to be fought out on stratigraphical and palæontological grounds. Nevertheless I feel bound to say that if the evidence furnished by the lithological composition of the ancient chalk and recent calcareous mud be correctly interpreted, we shall, at all events, detect in it nothing to warrant the conclusion that in no part of the oceanic areas yet explored is there any thing to be identified lithologically with the true Chalk. On the contrary, so far as the prevailing conditions of the existing sea-bed can be compared with those prevailing during the Cretaceous period, we shall not even detect valid

* I would take the opportunity of here stating that a great deal of the misconception prevailing as regards the rate and extent to which the purer siliceous deposits are produced by the *Diatomaceæ* and *Polycystina* is ascribable to the too prevalent practice of making arithmetical computations take the place of observed facts in matters connected with biology. When Ehrenberg remarked that "a single animalcule (meaning a Diatom), perfectly invisible to the naked eye, could, under favourable circumstances, possibly be increased in four days to 140 billions of independent animalcules, that two cubic feet of a stone similar to the polishing-slate or tripoli of Bilin might be formed in four days, and that these, multiplying again during only eight days of undisturbed organic activity, might in the same time afford a mass of silica which would equal the size of the earth," he simply played with figures. (See Scient. Mem. vol. iii. part x., April 1842.)

reasons for doubting the possibility of cretaceous rock, with intercalated flint-beds, being to this day in process of formation, inasmuch as the requisite materials are still forthcoming, and, as already urged, the physical conditions observable in the abyssal waters, after a certain depth is reached, have in all probability never altered to such an extent as to render a flint-bearing Cretaceous formation even improbable.

So far as I have been able to discover from the writings of the most recent authors who have discussed the mode of formation o the flints, their explanations have stopped short just where, in reality, the unique and by far most important and interesting points in the history of these structures may be said to commence. Thus we find it stated that, "by some means or other, the organic silex, distributed in the shape of sponge-spicules and other siliceous organisms in the Chalk, has been dissolved or reduced to a colloid state, and accumulated in moulds formed by the shells or outer walls of imbedded animals of various classes." We do not precisely know how the solution of the silica has been effected, though, when "once reduced to a colloid condition, it is easy enough to imagine it may be sifted from the water by a process of endosmose, the chalk matrix acting as a porous medium, and accumulated in any convenient cavities"*.

But it must be obvious at a glance that this furnishes no explanation whatever of the mode of production of the flints properly so called, but only of the fossilization or mode in which siliceous casts of organisms of various kinds imbedded in the chalk have been formed—the question of the mode of formation of the flint-beds, and their alternation with the strata of chalk (which is, in reality, the most remarkable and unaccountable of the whole series of phenomena), being left just as intact as before, no attempt having been made to show, even as regards the quantity of the siliceous material contributed from every recognized and available source, that, independently of the colloid-producing substance which constitutes an indispensable factor of the operation, there was enough silica present to meet the requirements of the case. Whence, then, did all the silica come? Why is it almost invariably found existing in layers parallel to the stratification of the Chalk? And what has really been its history, from first to last?

It is to these questions that I hope, on the present occasion, to be able to furnish such answers as shall, at all events, form the groundwork of a good working hypothesis, and one capable of further elaboration as time and opportunity permit. Meanwhile I may be allowed to state that the conclusions arrived at by me have their origin in the assumption that, in the nearly total elimination of the organic silica from the organic carbonate of lime, in the almost constant aggregation of the colloid silica around some foreign body, in the ultimate consolidation of the colloid material into nodular masses or more or less continuous sheets, in the stratification of these masses and sheets, and, collaterally, in the

* 'The Depths of the Sea,' by Sir Wyville Thomson, 1872, p. 482.

perfectly preserved state of many of the Cretaceous fossils, are to be discerned the successive stages of a metamorphic action, whereby the protoplasmic matter and silica present on the sea-bed, after having first passed through an organic phase capable of resisting disintegration and decay, became once more amenable to those purely material forces in obedience to which they entered upon their new and secondary phase as Flints *.

But, even yet, the chain of metamorphic action must have remained incomplete but for the manifest connexion which I was fortunately enabled, in 1860, to trace out between each of the successive stages referred to and a condition of things then for the first time noticed—namely, that the entire mass of animal life there present is confined to the immediate surface-layer of the muddy deposit, alternating periods being thereby established, during which one of the two predominant animal types (Foraminifera and Sponges) gradually overwhelms and crushes out the other over indefinite local areas, the strata of chalk in the one case, and the intercalated flint-beds in the other, being the issue of these contests.

Should it be asked, Why, then, do we find so striking a lithological difference between the Chalk and the Atlantic mud? The answer is, because our specimens of the mud represent only the constituent materials forthcoming at a depth of a few inches beneath the surface, where, if my hypothesis be correct, there must needs be accumulated nearly the whole of the silica. Whereas, were it possible to obtain specimens, say, from a depth of even a few feet, we should find that all, save the small residuary portion detected by analysis in the Chalk, had in like manner been eliminated from the mud.

Unfortunately, in such an inquiry, we have to deal with phenomena that, owing to the very nature of the conditions, must for ever present many conjectural points too important to be neglected, and yet too obscured in the Cimmerian darkness of the ocean to admit of experimental investigation under identical circumstances in the laboratory. Hence we are driven to fall back on hypothesis, in the hope of a time arriving when, by its means and improved appliances, we shall be gradually guided to the truth.

I will now state, in the form of three hypothetical propositions, the grounds upon which I have been led to infer that the chalk and calcareous mud † were formed under, at least, approximately identical conditions, and am still inclined to regard these two formations as not lithologically distinct.

1. Were it possible to compare a given quantity of chalk, in the condition in which it was formed at the bottom of the Cretaceous ocean, with a like quantity of recent calcareous mud, no such dif-

* Much valuable information "On Quartz and other Forms of Silica" will be found in a paper, bearing this title, from the pen of Prof. Rupert Jones, F.R.S. Unfortunately I was unable to avail myself of it, being unaware of its existence until the present communication had been laid before the Geological Society.

† The term "calcareous mud" applies throughout this paper to the common Globigerine ooze as met with in the Atlantic.

ference in the relative percentages of carbonate of lime and silica would be observable as could warrant us in pronouncing the two formations to be lithologically distinct.

2. Were it possible to compare a given quantity of the recent calcareous mud with a like quantity of the same material when finally converted into a calcareous rock, the difference in the percentages of carbonate of lime and silica would correspond closely with that now observable between the Chalk and the recent mud.

3. Were it possible to compare the percentages in, say, a hundred cubic feet of recent calcareous mud with those in a like cubic volume of flint-bearing chalk, they would be found to correspond, due allowance being made in each case for minor discrepancies resulting either from secular or local changes which affect the supply of material or the due increase of animal life*.

Before proceeding, however, to apply these propositions to the case of the flints it is essential that I should not only place beyond doubt the adequacy of the sources whence are obtained the vast quantities of protoplasm † and silica required for the production of the flint-formation, but should furnish satisfactory reasons for entering into much more detail on this portion of my subject than would under other circumstances be admissible. These reasons shall now be briefly stated.

I am prepared to prove that the main source of the protoplasm, as well as of the silica, is to be found in the substance described, in 1868, by Prof. Huxley, under the name of "*Bathybius*," and that this substance is neither more nor less than sponge-protoplasm derived from the deep-sea sponges which have been found swarming in certain regions of the ocean, and will, I believe, be eventually found to have constituted, in past geological periods, an all-important factor in the production, from organic materials, of probably all calcareous and siliceous rocks formed at the bottom of the sea.

In the 'Quarterly Journal of Microscopical Science' for Dec. 1868, Prof. Huxley described *Bathybius*.

In the succeeding number of that journal ‡ I endeavoured to show that *Bathybius*, together with the "Coccoliths," which were regarded by Prof. Huxley as forming part and parcel of its structure, do not represent any independent living type of being, that they stand in no physiological, but only in an accidental and purely mechanical relation to each other, and that analogy and the bulk of direct evidence are in favour of the supposition that this widely distributed protoplasmic matter is the *product* and not the source of the vital forces already in operation at the sea-bed.

In order to render intelligible the conclusion I arrived at with

* As a matter of fact, such discrepancies are at the present day encountered in the calcareous mud obtained from different regions, and even at different points in the same geographical area, the causes inducing them being, in all probability, of the kind suggested.

† I have used this term throughout the present inquiry as being less technical than *sarcode*, and less specialized than albumen.

‡ "On the Vital Functions of the Deep-Sea Protozoa," by G. C. Wallich, M.D. Quart. Journ. Micr. Science for January 1869.

regard to this substance, I must bring to my aid the descriptions given of it, the grounds upon which it had been pronounced by one eminent geologist and chemist to be not even of organic derivation, but an accidentally formed chemical product, and, lastly, the evidence furnished (strange to say, by those biologists who were the foremost to affirm its existence as a veritable "*Moneron*") in support of my contention that it is nothing more than sponge-protoplasm.

In 1868 Drs. Carpenter and Wyville Thomson wrote as follows:—"The remarkable abundance of sponges, which not improbably derive their nutriment from the protoplasmic substance (*Bathybius*) that enters so largely into the composition of the calcareous mud wherein they are imbedded, is a preeminently conspicuous feature of resemblance" between the mud and the chalk—a resemblance so striking, in their opinion, as to have led them to declare the mud to be not merely *a* chalk formation, but a continuance of *the* Chalk formation *.

According to Sir Wyville Thomson, "The Vitreous Sponges, along with the living Rhizopods and other Protozoa which enter largely into the composition of the upper layer of the chalk-mud, appear to be nourished by the absorption, through the external surface of these bodies, of the assimilable organic matter which exists in appreciable quantity *in all sea-water*, and which is derived from the life and death of marine animals and plants, and in large quantity from the water of tropical rivers" †.

"This calcareous mud is the *home of multitudes of exquisitely formed glassy and other siliceous Sponges; the chalk, on the other hand, may be said to contain no disseminated silica whatever*, beyond a few grains. . . . . . In one haul of the dredge, in the soft, warm, oozy, chalk-mud, were brought up upwards of forty specimens of vitreous sponges, many of which were new to science. . . . . . This mud was entirely filled with the delicate siliceous root-fibres of the sponges, binding it together like hairs in mortar. It was actually alive; it stuck together in lumps, as if there were white of egg mixed with it; and the glassy mass proved, under the microscope, *to be living sarcode*. Prof. Huxley regards this as a distinct creature, and calls it *Bathybius*. I think this requires confirmation" ‡.

According to Dr. Carpenter and Sir Wyville Thomson, "It seems highly probable that, at all periods of the earth's history, some form of the Protozoa (Rhizopods, Sponges, or both) predominated over all other forms of animal life in the depths of the sea, whether spreading, compact, and reef-like, as in the Laurentian and Palæozoic *Eozoön*, or in the form of myriads of separate organisms, as in the *Globigerinæ* and the *Ventriculites* of the Chalk" §.

In 1870 Prof. Huxley described *Bathybius* as "forming a living scum or film on the sea-bed, extending over thousands upon

* Proc. Roy. Soc. no. 107, 1868, p. 192.

† "On *Holtenia*, a Genus of Vitreous Sponges," Proc. Roy. Soc., June 1869.

‡ "On the Depths of the Sea," by Prof. W. Thomson, F.R.S. A paper communicated to the Ann. & Mag. Nat. Hist. for Aug. 1869, pp. 119–121.

§ *Ibid.* p. 124.

thousands of square miles, ... so that it probably forms one continuous scum of living matter girding the whole surface of the sea-bed" *.

In 1873, according to Sir Wyville Thomson, "there came up, imbedded in the Atlantic ooze, an extraordinary number of siliceous sponges." And referring to a dredging at a depth of 2435 fathoms, "in this, as in most other dredgings in the bed of the Atlantic, there was *evidence of a quantity of soft gelatinous organic matter, enough* to give a slight viscosity to the mud of the surface-layer. If this mud be shaken with weak spirit of wine, and if a little of the mud in which this viscid condition is most marked be placed in a drop of sea-water under the microscope, we can usually see, after a time, an irregular network of matter resembling white of egg, distinguishable by its maintaining its outline and not mixing with water. This network was seen gradually altering in form; and entangled granules and foreign bodies change their relative positions. *This gelatinous matter is therefore capable of a certain amount of movement, and there can be no doubt that it manifests the phenomena of a simple form of life*" †. "Entangled and borne along in the viscid streams of *Bathybius* we constantly find a multitude of minute calcareous bodies" ‡. And again, "one of the first results of deep-sea dredging was the discovery that the chalk-mud of the deep sea is in many places crowded with sponges" §.

In 1877 the same writer says, "Sponges extend to all depths; but perhaps the class attains its maximum development between 500 and 1000 fathoms. All the orders occur in the abyssal zone except the *Calcarea*. At great depths the Hexactinellidæ certainly preponderate. In the Atlantic the Hexactinellid sponges are very abundant to the depths of about 1000 fathoms along the coasts of Portugal and Brazil" ||. "Although all the principal marine Invertebrate groups are represented in the abyssal fauna, the relative proportions in which they occur is peculiar. Thus Mollusca, in all their classes, Brachyourous Crustacea, and Annelids are on the whole scarce; while Echinodermata and *Porifera greatly preponderate*" ¶.

We have now to look upon another side of this singularly phantasmagorian picture. Here is what Mr. Murray, of the 'Challenger,' stated on the subject in his report dated 1876, based on the researches of Mr. Buchanan:—"In the early part of the cruise many attempts were made by all the naturalists to determine the presence of free protoplasm in, or on, the bottoms from our soundings and dredgings, but with no definite result. It was undoubted, however, that some specimens of the sea-bottom preserved in spirit assumed a very mobile or jelly-like aspect, and also that flocculent

* Speech by Prof. Huxley, following the reading of a paper "On the Atlantic and Indian Oceans," by Capt. Sherard Osborn, R.N. (Proc. Roy. Geograph. Soc. for November 1870, p. 38).

† 'Depths of the Sea,' p. 410. ‡ *Ibid.* p. 413. § *Ibid.* p. 483.

|| 'The Atlantic,' by Sir Wyville Thomson, 1877, vol. ii. p. 343.

¶ *Ibid.* pp. 352, 353.

water was often present. Mr. Buchanan determined that the amorphous matter was simply the amorphous sulphate of lime precipitated by spirit from sea-water. . . . . In all cases the jelly-like or mobile aspect of the oozes was found to be due to the presence of the flocculent precipitate from the sea-water associated with the ooze. *No free albuminous matter could be detected.* When it is remembered that the original describers worked with spirit-preserved specimens of the bottom, *the inference seems fair that* Bathybius *and the amorphous sulphate of lime are identical, and that in placing it amongst living things the describers committed an error* " *.

We next come face to face with the opinion (somewhat distracting, it will be admitted), regarding the organic matter said to be diffused, as a kind of providentially served "broth" †, for the nourishment of the entire mass of the deep-sea Protozoa. On this point Messrs. Carpenter, Jeffreys, and Thomson wrote as follows in 1869 :—" But the most novel and important feature in these *analyses is the large quantity of organic matter indicated by them as universally* present in the water of the open ocean, *at great distances from land, and at all depths*" ‡.

Lastly, the following is Mr. Buchanan's commentary, published in 1876, on the last-mentioned remarkable fact:—" In connexion with carbonic acid, I may mention that I have frequently tested waters, and especially bottom-water, for organic matter. None of the methods in use for determining this substance in drinking-water giving satisfaction when applied to sea-water, I had to content myself with endeavouring to detect its presence. If the jelly-like organism which had been seen by some eminent naturalists in specimens of ocean-bottom, and called *Bathybius*, really formed, as was believed, an all-pervading organic covering of the sea-bottom, it could hardly fail to show itself when the bottom-water was evaporated to dryness and the residue heated. In *the numerous samples of bottom-water which I have so examined, there never was sufficient organic matter to give more than a just perceptible greyish tinge to the residue, without any other signs of carbonizing or burning*" §.

These extracts, it will, I think, be admitted, speak for themselves, and will be regarded by all who carefully peruse them as fully bearing out the following conclusions :—(1st) that there is no such living independent entity as *Bathybius*; (2nd) that the substance which received this appellation is undoubtedly sponge-protoplasm; and (3rd) that this sponge-protoplasm is almost universally distributed over those areas of the abyssal ocean that are occupied by the calcareous mud.

As regards " the identity of the amorphous sulphate of lime and *Bathybius*," as maintained by Mr. Buchanan, I have only to say that I do not for a moment call in question the fact of an amorphous condition of sulphate of lime being generated in sea-water, or muddy

* Proc. Roy. Soc. ('Challenger' Reports) vol. xxiv. no. 170, pp. 530, 531.
† Proc. Roy. Soc. vol. xxiii. no. 159, for Feb. 1875, p. 238.
‡ Proc. Roy. Soc. vol. xviii. no. 121, for Nov. 1869, p. 476.
§ Proc. Roy. Soc. ('Challenger' Reports) vol. xxiv. no. 170, p. 605.

water holding it in solution, under the chemical treatment described; but, with the greatest respect for the opinion of so able and conscientious an observer as Mr. Buchanan has proved himself to be, I am quite unable to accept his explanation that amorphous sulphate of lime and the glairy matter pervading and overlying the mud in such vast abundance and so universally, which was described as being actually alive and sticking together in lumps, as if white of egg were mixed with it, which, moreover, proved under the microscope to be "*living sarcode*," are, or can be, one and the same thing.

Fortunately the subjoined data relating to twenty samples of bottom obtained on board the 'Challenger' while traversing one of the most important and typical sections of the Atlantic, stretching across from Teneriffe to the entrance of the Caribbean Sea, furnish a complete verification of the opinion just expressed by me. According to analyses by Mr. Brazier*, the average quantity of sulphate of lime present in seven samples of "globigerine ooze," and twelve samples of "red clay," was only a fraction over 1 per cent., a quantity altogether insignificant, and obviously quite inadequate to account for the presence of such enormous masses of glairy protoplasmic matter as have been described, on the assumption that it is not true protoplasm, but merely a flocculent substance, derived, by an artificial chemical method, and only in the presence of alcohol, from sulphate of lime†.

It is deserving of mention, in relation to the sulphate-of-lime question, that in none of the published analyses of the deep-sea water or mud obtained during the cruises of the 'Porcupine' and 'Lightning,' in the years 1868–1870, have I been able to find any notice of that substance. This fact is of itself evidence, therefore, that no very material quantity of sulphate of lime was then met with; and putting all these facts together, it may, I submit, be safely concluded that not only once (as in the 2435-fathom dredging so graphically described by Sir Wyville Thomson), but on many other equally important occasions, the dredge must have plunged headlong into one of the ubiquitous sponge-beds—the glairy mass like white of egg, the multitudes of spicules distributed like hair in mortar throughout the mud, and the apparent residuum of contractile power in the glairy substance, said to have lingered in it even after it had been treated with alcohol, all furnishing distinct and unequivocal testimony to the fact that the substance in question was no allotropic condition of a salt of lime, but veritable sponge-protoplasm, existing under conditions, of all others, pre-eminently calculated to foster gigantic development.

In a very remarkable paper published in the 'Quarterly Journal of the Geological Society' in 1849, the late Mr. Bowerbank, while

* 'The Atlantic,' vol. ii. Appendix A, p. 369.

† As a matter of fact, twenty examples of mud were analyzed by Mr. Brazier; but as the twentieth was from the comparatively shallow depth of 450 fathoms, I thought it expedient not to include it in the estimated percentages. The percentage of sulphate of lime in it was, however, exactly 1 per cent. The general average is therefore in no wise vitiated.

discussing the properties of silica, says :—"But whence come the enormous quantities of silica which have entered into the structure of fossils during the geological period, and which still continue to be separated from the ocean? Various opinions have been offered to account for these phenomena, such as extreme heat, great pressure, thermal springs, and a peculiar gelatinous condition of silica, produced by chemical manipulation, but of which we have no authentic record in nature." "None of these," he continues, "appear satisfactorily to account for the vast deposits of silica that we have to deal with in connexion with organic matter. Great pressure and high temperature, there is no doubt, are active agents in promoting the solution of silica in excess, with which some mineral springs are charged, and these causes are perhaps powerfully effective in the formation of certain mineral products in the interior of the earth; but as regards the supply of silica in the production of fossils, and in its appropriation by living organisms, I believe them to have infinitely less to do with these phenomena than has hitherto been supposed. Much weight has been attached by some writers to the probability of the spicules of the Spongiadæ acting as nuclei for the attraction of silica in the process of their fossilization; but it is a remarkable fact that the true Halichondria, *in which the siliceous spicules abound*, are exceeding rare in the fossil state; while the remains of the true Spongia, *in which the animal* fibre predominates, are very abundant."

Now, to my mind, this looks very much like begging the entire question, inasmuch as it had long before been regarded as an established fact that, apart from all submarine sources of silica, there must through all geological time have been an inexhaustible supply of that material, derived from the disintegration of felspathic and other rocks, carried down to the ocean by rivers and currents—more, indeed, than the water can take up, judging from the barely appreciable quantity found to exist in it. Of the sufficiency of this supply there could therefore be no doubt, nor of the greatly augmented solubility of the silica under the operation of increased pressure and temperature, and, notably, the increased charge in the sea-water of carbonic acid. Neither can there be any doubt as regards the sufficiency of the organic agencies by which the silica held in solution was being perpetually removed, nor of the general tendency of silica, when undergoing solution, or in a colloid state, to seize upon some foreign body and become aggregated around it. These are all facts beyond dispute, the point requiring demonstration being:—Through what special agency does all this enormous amount of silica (after having been first eliminated from sea-water, and then secreted by living creatures in the shape of shells, reticular frameworks, or spicules, which constitute, as it were, the bones of the silica-secreting Protozoa) become once more transformed, *en bloc*, into such masses of mineral as the flints?

Of these questions Mr. Bowerbank's observations furnish no approach towards a solution.

The only arguments I think it requisite to answer in detail are those used by Sir Charles Lyell, which were cited in an earlier part of these observations. It is, I trust, needless for me to say that in venturing to contest any opinion emanating from so illustrious a source, I do so with the greatest reluctance, and only under a conviction that his conclusions, however justified by the data which were at his command in relation to the profusion of the Diatomaceæ in the Atlantic, and the predominating share taken by these organisms in the formation of the flints, were vitiated in consequence of the data being erroneous. For, I repeat (and without fear of contradiction) that in the North Atlantic, to which Sir Charles Lyell's remarks applied more particularly, there never has been met with a true calcareous mud in which the percentage of Diatom-remains is so great as to deserve mention in connexion with the flint-formation. Neither is there any authentic evidence forthcoming to show that Diatomaceous deposits have in time past existed, at depths such as that indicated (2400 feet), along the North-Atlantic coast-lines, of sufficient importance to deserve mention. Where they occur they are of Posttertiary origin, and have been formed in freshwater bottoms. Should this be granted, there is the clearest warrant for assuming that the comparatively bulky siliceous framework and spicule-system of the deep-sea vitreous sponges must constitute the main source of supply of that material for the flints. Indeed it is far from improbable that the true flints are produced solely in the areas occupied by the sponge-beds, the flints becoming more cherty and devoid of those characteristic amœbiform outlines which, according to my hypothesis, are dependent on the presence of, and the combination of the silica with, the accumulation of nearly pure protoplasm still sufficiently recent to have resisted admixture with calcareous or other matter.

But it is not only necessary that an adequate supply of fresh and free protoplasm should be present at the sea-bed, but that protoplasm, not of necessity pure and homogeneous, should be present in a continuous flocculent layer overlying the calcareous deposit. Now this is precisely the condition in which the subsidiary portion exists which is not derived from the sponges, but from the Foraminifera. This very remarkable condition, of the full significance of which I was not aware till the history of the deep-sea sponges was revealed some ten years ago by Dr. Carpenter and Sir Wyville Thomson, was first pointed out by me in 1860 as occurring over the Globigerine areas of the North Atlantic; and it has since then been completely verified by the above-named observers. As it furnishes the key to the entire process of flint-formation, I may be permitted to cite the description given of it in part 1 of my 'North-Atlantic Sea-bed,' published in 1862.

"The flocculent character is distinctly observable on the immediate surface-layer of all the deposits, and in a few cases, in which the quantity of extremely fine amorphous particles is excessive, it extends to some depth. Such is the condition where the Foraminifera are either absent or constitute the smallest percentage of the material. But, in the majority of the deposits, the flocculence does not extend beyond half an inch, or an inch, below the surface, and it is then replaced by a stratum of the utmost tenacity. This marks the limit of the amorphous non-mineral particles, and the point at which the consolidation of the heavier atoms begins. It appears probable that the living *Globigerinæ* are altogether confined to this superficial stratum." (*Op. cit.* pp. 138, 139.)

Of the source of the subsidiary protoplasmic layer but little need be said in this place beyond pointing out that a very considerable portion of it is, in all likelihood, derived from the *Globigerinæ*, which constitute, as a rule, from 70 to 85 per cent., but in certain rare instances as much as 95 per cent. of the entire surface stratum of the calcareous deposit itself. The quantity furnished by the *Globigerinæ*, irrespectively of the other Rhizopodal families associated with them in varying, but always in comparatively insignificant proportions, must therefore be very considerable.

It has been shown how vast must be the supply of organic silica derived from the deep-sea Sponges. It is therefore quite intelligible why, so long as this predominant source both of protoplasm and silica remained unrecognized, undue weight should have been attached, by some writers, to the quantity of the latter material provided by the *Polycystina*, *Diatomaceæ*, and the still less numerous forms of siliceous-shelled Protozoa, and by others to the quantity brought in solution by the waters of the ocean from land sources. That the siliceous remains of the organisms referred to do occasionally occur in sufficient abundance to satisfy the wants of the microscopist, is indisputable. The silica of the flints cannot, however, be said to depend, in any great degree, on these microscopic forms, as any one familiar with the extent and structure of the siliceous skeletons and spicules of the sponges will admit. But, in addition to this, I can state with confidence that in no part of the North Atlantic, where the Globigerine mud prevails (the mud declared to be a continuation of the old chalk), do the remains of *Polycystina* or *Diatomaceæ* constitute, at the most, more than from 4 to 6 per cent. of the entire deposit; and in no instance do they occur, either separately or collectively, in such numbers as to interfere with or "mask" the typical character of the calcareous mud; nor, if we look at the matter only in its relation to the flints, can we come to any other conclusion than that their production, though of course increased to a very trifling extent by accessions of silica from the whole of the subsidiary sources alluded to, would not have been appreciably influenced had the *Polycystina* and *Diatomaceæ* been altogether wanting*.

* I have to observe in this place that it has been too much the custom in estimating the percentage of the various materials present in the deep-sea deposits, whether organic or inorganic, to base inferences on what is observed under the microscope, quite forgetting that all mounted objects such as Diatoms or Coccoliths are not even visible except as mere specks, unless seen under the higher powers of the instrument. To identify the form of a Coccolith, for example, under a lower power than $\frac{1}{4}$ objective, is almost impossible; but in order to see it at all the whole of the heavier particles must be entirely removed, and the lightest particles, amongst which are the Coccoliths and Diatoms, must be separated by a process of elutriation. To deduce percentages from elutriated residues is obviously, therefore, misleading in the highest degree.

A very important fact has to be here noticed in relation to the siliceous materials which are supposed to be normally and uniformly distributed throughout the substance of the calcareous mud at the period of its deposition on the sea-bed. In order to understand the full significance of this fact, it is indispensable to recollect that, whereas the carbonate of lime of the effete Globigerinæ and other Foraminiferous shells is to a certain extent redissolved in the water charged with an excess of carbonic acid, and the amount thus abstracted is too insignificant to produce any material diminution in the mass of the calcareous deposit, nearly the whole of the organic, and probably a not inconsiderable proportion of the inorganic silica which has been found present in some specimens of the Atlantic mud is dissolved under the conditions that prevail. For, whereas the calcareous matter is furnished partly from the débris of Foraminifera which pass their existence only at the bottom of the ocean, and partly from such as live at the surface and subside to the bottom only when dead, *the whole of the silex-secreting organisms, with the solitary exception of the sponges, subside to the bottom only after death*, this being equally true whether the *Polycystina* inhabit the entire body of the ocean from its surface to its bottom, or live only near or at its surface *. The result is, that the *whole* of the organic silica, the moment it reaches the bottom, comes into contact with the protoplasmic layer and is retained by it. *Hence the quantity present in every sample of mud obtained* (*as all our samples hitherto have been*) *by a mere dip into the superficial stratum of a few inches in depth, does not fairly represent the percentage of silica contained and supposed to be equally distributed in the substrata, but only the accumulated amount of that substance which has been getting accessions for an indefinite period from the superincumbent waters.*

In the case of the sponges that occur in such numbers on every square yard of the calcareous mud, and live more or less imbedded in the soft and luxuriantly developed nidus of their own protoplasm, the result described must necessarily take place in a still more signal degree, since every spicule, and every particle of their siliceous débris, is not only formed but accumulated within this protoplasmic environment. Therefore, instead of there being from 25 to 35 per cent. of silica, soluble and insoluble, in the calcareous mud, at a depth, say, of eighteen or twenty-four inches below the surface, there is in all probability not more than is to be met with in an average specimen of white chalk.

If we follow out to its legitimate issue a continuance of such conditions as have been here described, it is obvious that a period must

* It will be seen on reference to my 'North-Atlantic Sea-bed,' p. 127, and also in a paper on the *Polycystina*, in the 'Quart. Journ. Micros. Science' for July 1865, that I then called attention to the fact that the *Acanthometræ*, which are abundantly represented in the surface-waters of the ocean, are not purely siliceous, and therefore yield to the solvent action of acids, and even of water, much more readily than any other siliceous-shelled Protozoa with which we are acquainted. Not a trace of their siliceous remains is to be found either in recent or fossil oceanic deposits. This fact has been completely verified by Sir W. Thomson, in his work 'The Atlantic,' vol. ii. p. 340.

arrive when the protoplasmic masses (which, owing to their inferior specific gravity, always occupy this position in relation to the calcareous mud upon which they may be said to float so as to form an intermediate stratum between them and the superincumbent water) will become, if not supersaturated with silica, at all events so highly charged with it in a now colloid state more and more closely approaching coagulation, as eventually to asphyxiate—so to speak—the very organisms which have produced them.

If we turn to the less prominent, because negative, conditions that prevail at the sea-bed, we shall perceive that they are of a kind specially favourable for securing uniformity of results both as regards the time occupied in their completion, and the nature of the changes which are effected by them. Thus we know that the abyssal waters closely bordering on the sea-bed itself are, in the majority of cases, in a state so nearly approaching perfect quiescence, that no current of sufficient energy exists to divert from their downward course particles of matter so light and feathery as to have taken probably many weeks, if not months, to sink down from the surface of the sea to their final resting-place at the bottom. On the other hand, there is nothing as yet known that could lead to the inference that the periods required for the deposition and consolidation of each succeeding stratum of chalk, and its accompanying stratum of flints, bear any proportion to those gradual and more rarely recurring secular changes in the direction of the great oceanic currents which (to repeat Sir Charles Lyell's words) favour at one time in the same area a supply of calcareous, and at another of siliceous matter; whilst, as a natural consequence, the prevailing uniformity of the physical conditions must inevitably engender a corresponding uniformity and simultaneousness in the development, growth, and final death and decay of the various lower forms of life that are under its influence. If this be true, we might expect that over large areas of the calcareous sea-bed a very preponderating number of the sponges would, almost simultaneously, spring into existence from the germs or gemmules left by a preceding generation, and as simultaneously multiply and die, to be succeeded in turn by another generation, and so on. We are thus furnished with an auxiliary, though (as I shall presently show) by no means the most important factor, in determining the simultaneous production of the flint nodules and sheets over extended horizontal areas.

Although the analyses now about to be quoted are somewhat out of place in this portion of my paper, I introduce them here as a requisite preliminary to some observations on colloid phenomena which follow, it being of importance that their bearing on these should be clearly understood.

The first of these analyses to which I have to direct attention is one, by the late Mr. David Forbes, of a sample of "Atlantic ooze," obtained from a depth of 1443 fathoms to the south-eastward of the Rockall shoal, off the north-west coast of Ireland, during the cruise of the 'Porcupine' in 1869. "A complete analysis of this sample," Mr. Forbes observes in his Report, "shows its chemical composition to be as follows :—

"Carbonate of lime	50·12
Alumina (with phosphoric acid) soluble in acids	1·33
Sesquioxide of iron, soluble in acids	2·17
Silica in a soluble condition	5·04
Fine insoluble gritty sand (rock débris)	26·77
Water	2·90
Organic matter	4·19
Chloride of sodium and other soluble salts	7·48
	100·00

"If we compare the chemical composition as above with that of ordinary chalk, which consists all but entirely of carbonate of lime, and seldom contains more than from 2 to 4 per cent. of foreign matter (clay, silica, &c.), it will be seen that it differs chiefly in containing so very large an amount of rock matter in a fine state of division. If we subtract the water, organic matter, and marine salts, which would probably in greatest part be removed before such mud could in process of ages be converted into solid rock, even then the amount of carbonate of lime or pure chalk would not be more than, at highest, some 60 per cent. of the mass. As regards the probable origin of the pebbles and gravel found in the various dredgings, it will be seen from the description* that they consist principally of fragments of volcanic rocks and crystalline schists. *The former have in all probability come from Iceland or Jan Meyen*, whilst the latter have probably proceeded from the north-west coast of Ireland."

The next analysis is by Mr. W. J. Ward, and was made in the Chemical Laboratory of the Geological Museum, Jermyn Street. It is taken from 'The Memoirs of the Geological Survey,' vol. iv. p. 15 (by Mr. Whitaker, B.A.), the material being a sample of "the Upper Chalk with Flints" from the vicinity of Gravesend. In this there were in 100 parts of the chalk :—

Carbonate of lime	98·52
Ignited insoluble residue, chiefly silica	·65
Sulphate of lime	·14
	99·31

The remaining fractional parts consist of other materials in very minute quantities.

Lastly, there are two analyses of grey and white Chalk which I quote from an address delivered by the President, Mr. Prestwich, at the Anniversary Meeting of the Geological Society in Feb. 1871—an address replete with valuable information of all kinds bearing

* A separate description is given of these 617 subangular fragments, in general not above ¼ to ½ grain in weight, the biggest only weighing 3 grains ('Depths of the Sea,' 1872, Appendix C, p. 514).

on deep-sea exploration down to the period in question. These analyses, like the first of the above, are by the late Mr. David Forbes, whose note on the subject I here transcribe:—"The specimens of Atlantic mud which I have examined differ very essentially from chalk in composition; and no single one of them (if consolidated) could be entitled to the appellation of chalk, as ordinarily understood by geologists or chemists. In order to make a correct comparison of their composition with that of chalk, I was obliged to make analyses of the latter rock, two of which I annex:—

	Grey Chalk (base of), Folkestone.	White Chalk, Shoreham, Sussex.
Carbonate of lime	94·09	98·40
Carbonate of magnesia	0·31	0·08
Insoluble rock débris	3·61	1·10
Phosphoric acid	traces.	....
Alumina and loss in analysis	....	0·42
Chloride of sodium	1·29	....
Water	0·70	....
	100·00	100·00"

Referring to these, Mr. Prestwich observes, in a later part of his address:—"From what I have previously said, you will have understood that, lithologically, there is but little resemblance between the Atlantic mud and our typical white chalk, none that could ever have led a geologist into any error of determination. In fact, in no part of the area yet explored is there any thing at all to be identified lithologically with the true white chalk. Even if it were found that the superposition were conformable, the difference of mineral character is too marked. At the same time it is to be observed that *the area of the Atlantic is so vast that, variable as the deposit now going on seems to be, it is probably little, if any, more so than that which went on in some parts of the Chalk series in the bed of the Chalk ocean over the old European area. Of the rate of the present deposit we know nothing.* Is it even going on everywhere over the deep Atlantic?"

Again, Mr. Prestwich says:—"The Atlantic abyssal mud has been found to contain from 50 to 60 per cent. of carbonate of lime, 20 to 30 of silica, with small variable proportions of alumina, magnesia, and oxide of iron. Its appearance, when dry, is chalk-like; but it is to be observed that our chalk is a much more homogeneous rock, containing from 95 to 99 per cent. of carbonate of lime, while even our grey chalk contains from 80 to 90 per cent. The large proportion of calcareous Foraminifera in the chalk, and of siliceous *Polycystina and vitreous Sponges in the Atlantic mud*, may, however, render this rather a question of proportion than of radical difference."

Lastly, I have to cite Sir Wyville Thomson's most recently formed opinion on the subject, as expressed in his work 'The Depths of the Sea' (pp. 480, 481). "It would seem," he says, "from the analysis of chalk, that siliceous organisms were entirely wanting in the ancient Cretaceous sea. In chalk-mud, on the other hand, silica is found in abundance, in most specimens to the amount of from 30 to 40 per cent. A considerable proportion of this is inorganic silica—sand; and its presence is doubtless due to the circumstance that our dredgings have hitherto (1872) been carried on in the neighbourhood of land and in the path of currents. . . . . A considerable proportion of the silex of the chalk-mud, however, *consists of the spicules of Sponges*, of the spicules and shields of radiolarians, and of the frustules of Diatoms. *And this organic silica is uniformly distributed through the mass.*"

Now three distinct and important Assumptions demand attention in connexion with these reports and analyses.

In the first place, the assumption on which it will be remembered a good deal of emphasis was laid by me at the beginning of this paper—namely, that the chalk, as we now find it, gives on analysis any thing like an accurate or, let me say, an even approximately accurate idea of the percentage of silica, organic and inorganic, present in it when it existed in the shape of calcareous mud at the bottom of the old Cretaceous sea.

In the second place, the assumption (for it is obviously quite impossible that it can be any thing more in the present state of our knowledge, as to what may, or may not, be found a very few inches beneath the surface of the muddy deposit) that a specimen of bottom obtained from such a thin superficial stratum (where, according to my hypothesis, nearly the whole of the silica is either dissolved or stored up that has been gradually accumulating since the stratum of nascent chalk deposited simultaneously with it) furnishes a trustworthy index to the lithological constitution of any portion of the subjacent mass.

And, in the third place, the assumption that the special analyses of "Atlantic mud" which have been cited—and which are the only ones heretofore published, so far as I can discover, that have guided scientific opinion on the subject—furnish a fair indication of the quantity of insoluble silica ("rock débris" of sorts) which is to be found in samples of the typical mud procured from oceanic areas sufficiently remote from currents capable of transporting such débris from volcanic or other regions.

As regards one and all of these questions, I venture, for reasons already adduced, to believe that generalizations have been formed and relied upon which were based on data more or less inapplicable in each case, and were, consequently, in themselves faulty; and, further than this, with the most implicit faith in the absolute accuracy of the analyses, both of my late friend Mr. David Forbes and of Mr. Ward, I venture to affirm that, in the case of the former, no more unfortunate and misleading example of "Atlantic mud" could have been placed in the hands of this accomplished geologist and chemist than that which was obtained from a position to the south-eastward of Rockall. I know the ground from having traversed it a little to the northward, in the 'Bulldog,' in 1860; and being thus able to form an opinion as to the probable source, of a large proportion at least, of the rock débris and volcanic detritus which was found mixed with the mud in this region, I think there cannot be a doubt as to these having been derived from the sources suggested by the analyst. In most of the samples of mud obtained in that oceanic area, and more particularly in the tract extending across to the north-westward from the Faroes to Iceland, and again from the north-western point of Rockall in a north-westerly direction towards Cape Rekianess in Iceland, I almost invariably detected more or less rock débris mingled with well-marked volcanic materials. I shall show presently why I consider the specimen of Atlantic mud analyzed by Mr. Forbes, to which such a prominent place has been given, a *most* unfortunately chosen one. But meanwhile, I would observe that there is every reason to believe that, in the open portions of the North Atlantic, the really typical mud supposed to represent the Cretaceous material is more or less entirely devoid of débris of this kind. But, for all this, the subject is in many respects puzzling and complicated, inasmuch as pieces of rock of considerable size have undoubtedly been found by me in mud obtained at such distances from land as to render it extremely unlikely that they could have been drifted by even the strongest currents known to prevail anywhere out at sea in those latitudes. Moreover, as this occurs in oceanic areas which for ages have not seen the bottom of an iceberg or even large masses of drift-ice—probably not since the Glacial period—the rock débris can scarcely be traceable to that agency. Nor is it likely that it can have been transported and dropped by fish; for the question at once arises, Where could fish get it from? And surely the rock débris could not have lain to this day in its present position at the sea-bed, uncovered, to any extent, with sedimentary deposit, since the period when the areas in which they occur were shoal-water areas, and therefore subject to the influence of currents capable of moving such masses to long distances*.

Under these circumstances it is desirable that the following additional facts indicating the exceptional condition of the sea-bed in the channel between the Rockall shoal and the north-west coast of Ireland should be made more generally known than they appear to be. It will be seen how well founded was Mr. David Forbes's surmise that the volcanic detritus in the 1443-fathom mud had been drifted either from Jan Meyen or Iceland, when I state that between the Faroes and the south-western part of Iceland there exists a channel where we found a depth of 680 fathoms. The sounding was a most important and interesting one, since it was here that I obtained the first clear and really indisputable evidence of the presence of animal life at such a depth. From the nature of the creatures brought up, and a number of conclusive facts to which I need not now refer more particularly, but which have also already been fully described by me †, there are the strongest

* This subject was fully discussed in a paper contributed by me to the 'Quart. Journ. of Science' for Jan. 1864, and also in my 'North-Atlantic Sea-bed,' pp. 3–7.

† North-Atlantic Sea-bed, pp. 3–7 and 147.

grounds for believing that the spot at which the sounding was taken is a rocky one, and swept clear of any deposit by a current setting nearly due south from Jan Meyen, and, as will be seen on reference to any chart, flowing down in nearly a direct line to the channel between Rockall and the Irish coast. Yet, in the 'Proceedings of the Royal Society' (for Nov. 1869), the statement is put forward by Dr. Carpenter that, "*save in the narrow channel of* 682 *fathoms, there is no depth greater than* 300 *fathoms along the whole of the bottom* (from the Faroes to Iceland), and an effectual barrier is thus interposed to any current moving southwards at a depth exceeding this"*. Whilst in the 'Proceedings' for June 1872† this extraordinary assertion is repeated in a still more misleading fashion; for here Dr. Carpenter says, "*In my Report for* 1869, *I pointed out that the comparative shallowness of the bottom between Iceland and the Faroe Islands would interpose an effectual barrier to any glacial current moving southward at a depth exceeding* 300 *fathoms*,"—the result of these misstatements being that, in the chart appended to Sir Wyville Thomson's 'Depths of the Sea,' in the chart appended to Captain Davis's paper "On the Course of the 'Valorous'" in 1874 (published in the 'Geographical Magazine' for October 1875), and in the chart appended to Captain Markham's 'Threshold of the Unknown Region' (published in the same year), the 680-fathom channel is altogether omitted, the greatest depth recorded in these charts between Iceland and the Faroes, being in the former 500 fathoms, and in the two latter only 250 fathoms! So far, moreover, from its being a fact that there is no depth greater than 300 fathoms, I may mention that in the two soundings, taken respectively at a distance of fifteen miles to the eastward and westward of the 680-fathom bottom, the depths discovered were 350 and 368 fathoms. As I had the honour of presenting Dr. Carpenter, in 1862, with a copy of my work, in which there is a chart setting forth all these particulars, I am somewhat at a loss to conceive how he could have committed such an error. Indeed it is impossible to explain it on any other supposition than that this author's well-known scientific ardour caused him to remain blind to the fact that the presence of the 680-fathom bottom in this region was fatal to the theory he was at the time propounding with reference to the deep oceanic circulation of this particular region. On the other hand, it is but an act of justice to those who superintended the soundings on board the 'Bulldog' in 1860, to state that these could not have been more ably conducted or more thoroughly trustworthy in every respect.

Bearing in mind, then, the various circumstances now referred to, I think we are fully justified in concluding that, for the purposes of exact analysis and comparison (such analysis as can alone be of service to the geologist), the whole of the methods heretofore employed for obtaining an insight into the precise lithological composition of the rock-material now forming at the bed of the ocean

* Proc. Roy. Soc. for November 1869, vol. xviii. No. 121, p. 464.
† Proc. Roy. Soc., June 1872, vol. xx. No. 138, p. 591.

have been singularly insufficient, however valuable they may be (and valuable they unquestionably are) to the naturalist and biologist*.

It is therefore quite possible that on analyses being made of mud procured from oceanic areas free from any source of exceptional mineral admixture, the percentage (30 per cent. or thereabouts) of soluble and insoluble siliceous materials which has been supposed to apply to the Atlantic mud generally may much more closely approximate to the small residuum which is known now to exist in the Chalk. In connexion with this subject I cannot refrain from quoting an admirable passage in Professor Prestwich's Address, to which I have already been so deeply indebted. It is as follows :—"In one point of view, the geologist has the advantage over the naturalist. The latter examines the coasts, and dredges in the ocean, but he can only skim the surface, whereas the former has the old sea-beds opened out to him. . . . . What may be under the surface of the Atlantic mud we know not. Is there a succession of strata extending down to the equivalents in time of our chalk strata? or would the equivalent of the latter prove to be merely one part of a series, the other end of which would convey us back to the Oolitic, Jurassic, Triassic, or even Carboniferous times? . . . . The present explorations, full of interest and valuable as they are, are insignificant compared with the vast area of the ocean" (*loc. cit.* pp. 49, 50).

It now only remains for me to complete the present preliminary sketch of the agencies concerned in the formation of the flints from the materials present wherever the calcareous mud of the Atlantic is to be found, by stating that the Stratification of the Flints is due to the fact, already touched upon in a previous page, that nearly the whole of the silex derived from the Sponges on the one hand, and the continual subsidence of minute dead siliceous organisms on the other, is retained in the general protoplasmic layer which I have shown maintains its position on the immediate surface of the calcareous deposit, and gradually dissolves the silex. This layer, in virtue of its inferior specific gravity, rises with every increase in the thickness of the deposit, until, at last, the supersaturation of the protoplasmic masses with silex takes place, and the first step towards the consolidation into flint is accomplished—the continuity of sponge-life, and of the various other forms which tenant the calcareous areas, being secured through the oozy spaces which separate the sponge-beds, and thus admit of both adult and larval forms having free access to the overlying stratum of water.

That the predisposition of silica, itself in reality a colloid, to form colloidal combinations with albuminous and other materials

* In 1863, at a Meeting of the Royal Geographical Society, I exhibited various forms of deep-sea apparatus, and amongst these a *Pelimeter*, specially designed by me for penetrating the deep-sea deposits to a considerable distance and bringing up a *core* about 2 inches in diameter and from 10 to 15 inches in length. The instrument was also adapted for giving distinct indications of rocky bottom. This Pelimeter was highly spoken of by Sir Roderick Murchison on the occasion referred to. (See 'Proc. Roy. Geograph. Soc.' vol. vii. No. 2, 1863.)

was known long before deep-sea exploration was dreamt of, is a well-known historical fact; it has been alluded to by most of the writers who have attempted an explanation of the mode of formation of the flints. But the various conditions that present themselves, from the earliest elimination of the silica from the sea-water to the period when it becomes finally consolidated, have never, that I am aware, been consecutively followed out.

There is one distinguished authority, long since deceased, whose unpretentious little volume, 'Researches in Theoretical Geology,' is so pregnant with valuable suggestions, which clearly pointed to truths then only looming in the far future of his cherished science, that no apology, I am sure, is needed for offering a short extract from his remarks on the present subject. I allude, of course, to Sir Henry De La Beche. To him, or rather through him in this particular instance, are we indebted for the first clear suggestion in reference to the peculiar molecular behaviour of comminuted particles of silica when kept for a time in suspension along with clayey matter in water. He stated that, according to Mr. Babbage, the mode of formation of the chalk flints received an illustration in the common process of preparing the plastic substance for the potteries: when flints, having been previously burnt and ground, were suspended with clayey matter in water, a deposit was produced which possessed the requisite distribution of the particles of silica among the clay for pottery purposes; if this compound were used in proper time, the siliceous particles remained disseminated; but if allowed to continue too longat rest, the silica became aggregated into small lumps, and the mass was rendered useless for the manufacturer *.

But that the colloidal *idiosyncrasy* of silica performed a much more important function in the phenomena connected with the flints than has heretofore been supposed, appears to me to be indicated by the evidence of the almost perfect incorporation of the organic silica with a colloid material, the unique *Amœbiform* nodulation of the flints, and its homogeneousness, whether occurring in nodules, in continuous sheets parallel to the stratification, or as sluggish overflows into fissures in the Chalk. But for a very highly developed colloidal condition of the materials these peculiarities could not, I conceive, have presented themselves so uniformly throughout the formation. From a mere aqueous solution the deposit of silica would have exhibited totally different characters; there would have been a general infiltration into the substance of the chalk, the particles of which would thereby have been cemented together, so as to form a siliceous limestone; the various minute organic forms in which the silica showed itself, though, no doubt, capable of solution to a limited extent in water charged more or less highly with carbonic acid, and aided perhaps by the stupendous pressure, would have occasionally left more pronounced traces of their original structure than is observable in the body of the flints; probably all the fossils would have been either infiltrated with silica, or a substitution of that substance would have taken place even more

* Published in 1834, pp. 98, 99.

frequently than we find it; there would have been no signs of the specific contractility pertaining to colloidal silicic acid; the resulting siliceous mineral instead of appearing, when not rendered cherty by insoluble matter, as "*a colloidal glassy hyalite*," would have presented itself either as compact quartz, or possibly as an alkaline silicate; and, lastly, there would have been wanting the evidence of the greater portion of the siliceous material having been, as it were, continuously waylaid and absorbed, as it descended from the surface of the ocean, into the colloidal protoplasmic mass resting upon the immediate upper surface of the calcareous deposit.

If we compare the evidence thus furnished of marked colloidal action with what is known of the properties of silicic acid when in the presence of another powerful colloid, and favoured by the nature of the conditions as to unlimited time, low temperature, the presence of various alkaline substances and finely comminuted mineral matter, and the reign of almost perfect quiescence, I think it will be admitted that, although many doubtful and obscure points still remain to be elaborated, as a whole the view here advocated receives substantial confirmation in most of its leading particulars*.

In conclusion, I beg to express a hope that, although the length already attained by the present communication has debarred me from bringing forward a number of important facts and observations which would have materially strengthened my arguments, considering the complex nature of the inquiry and the special difficulties belonging to it, the following conclusions have, on the whole, been fairly sustained:—1. That the silica of the flints is derived mainly from the sponge-beds and sponge-fields which exist in immense profusion over the areas occupied by the Globigerine or calcareous "ooze." 2. That the deep-sea sponges, with their environment of protoplasmic matter, constitute by far the most important and essential factors in the production and stratification of the flints. 3. That, whereas nearly the whole of the carbonate of lime, derived partly from Foraminifera and other organisms that have lived and died at the bottom, and partly from such as have subsided to the bottom only after death, goes to build up the calcareous stratum, nearly the whole of the silica, whether derived from the deep-sea sponges or from surface Protozoa, goes to form the flints. 4. That the sponges are the only really important contributors to the flint-formation that live and die at the sea-bed. 5. That the flints are just as much an organic product as the Chalk itself. 6. That the stratification of the flint is the immediate result of all sessile Protozoan life being confined to the superficial layer of the muddy deposits. 7. That the substance which received the name of "*Bathybius*," and was declared to be an independent living Moneron, is, in reality, sponge-protoplasm. 8. That no valid *lithological* distinction exists between the Chalk and the calcareous mud of the Atlantic; and

* See a paper, by the late Mr. Graham, "On the Properties of Silicic Acid," in the Proc. Roy. Soc. for June 1864, in which will be found a number of interesting facts bearing upon the hypothesis put forward by me. I would particularly direct attention to pp. 335–337.

pro tanto, therefore, the calcareous mud may be, and in all probability is, "a continuation of *the* Chalk formation."

Discussion.

The President stated that he had formerly studied this subject, and come to the conclusion that, though deep-sea mud differs from Chalk in many important particulars, yet still it was sufficiently related to warrant a comparison. Since the remains of siliceous organisms are absent from the Chalk, but flints present, whilst in the deep-sea mud siliceous organisms are abundant and flints absent, probably the material of the flints had been to a greater or less extent derived from these organisms. Much, however, remains to be learned.

Mr. Evans said that the author seemed to have given a *vera causa* for the intermittent character of the Chalk flints. He doubted if the protoplasm could be in any sense a producer of flint. There was always a certain amount of silica in solution in sea-water; and there seemed evidence that, after the deposition of the beds, a considerable quantity of silica was aggregated by a sort of dialyzing process. This was shown by the deposition of flints in walls in the Chalk &c., so that it was possible that the absence of flint from intermediate layers might be partly accounted for in this way.

Mr. Charlesworth said the origin of flint was in great confusion. He recapitulated some of the views which had been entertained on the question. He said that the author was mistaken in supposing that Dr. Bowerbank and Dr. Mantell agreed as to the origin of flint; for the latter did not suppose every piece of flint to be a sponge.

Prof. Seeley thought the author had neglected the geological history of the occurrence of flint. He thought the fissures filled with flint, and the tabular layers investing nodules, showed that probably the flint had gradually come into existence in the Chalk. The flint in the fissures must be, as it were, filtered from the Chalk. In dealing with the question we must remember how flint occurred in other formations; and the question which dealt with the occurrence of flint in the Chalk must deal with it in other formations, and as replacing shell and coral, as filling cavities without replacing the shell, and as external investing masses round fragments of fossils. He thought that the flinty masses of the Chalk were very analogous to the septarian masses of the clays, and that the flints had grown, and even now were growing. The researches of Dr. Graham on dialysis had cleared up the way in which flint in Chalk may become soluble.

Mr. Whitaker remarked that previous speakers had said most that he had to say. It must be remembered that flints occurred not only in layers of nodules but in tabular layers, as in the Isle of Thanet; several of these at the present day were water-bearing, which would be favourable to the theory of subsequent formation. It was probable that flint had been deposited in more than one way.

It would be interesting to compare analyses of Chalk where there were many and where there were no layers of flint. He mentioned a case where one of the green-coated flints at the base of the Thanet sand was imbedded in a band of white flint in the Chalk below, which latter, therefore, must have been formed round the former.

Mr. Hudleston said that Mr. Mortimer, in a recent paper, had stated that the upper flintless Marsupite Chalk of Yorkshire contained twice as much silica as the middle or flint-bearing Chalk. At North Grimston, in the Coral Rag, where the beds were flat, there was no flint; where they were bent, there were many flints.

Dr. Wallich said Mr. Charlesworth had quite misunderstood him about Dr. Bowerbank's and Mantell's views. The time at his disposal forbade his going into the whole question; but, briefly, his view was that the sponges attracted the colloidal silica which existed at the surface of the mud.

8. Petrological Notes *on the* Vicinity *of the* Upper Part *of* Loch Maree. By Rev. T. G. Bonney, M.A., F.R.S., Sec. G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read December 3, 1879.)

The relations of the rocks on the western border of Ross and Sutherland have long been a subject of controversy. Into the details of this it is needless to enter on the present occasion, as they have been recently recapitulated by Mr. Hudleston in a luminous critical sketch communicated to the Geologists' Association and published in their Proceedings*. The materials for this sketch are mainly contained in our own Journal; and the last contribution to the subject was a paper read by Dr. Hicks on May 22, 1878†. After listening to the ingenious theory put forward by that author, it occurred to me that the question was one on which the testimony of the microscope ought to be especially valuable. According I spent some days last summer at Kinlochewe, in order to examine the rocks in the field and to obtain specimens for microscopic work. I have now the honour of laying before the Society the results of these investigations.

(1) *Syenite of Glen Laggan.*

Previous writers on the above section have agreed in stating that a mass of igneous rock makes its appearance on the floor of Glen Laggan, about two miles from Kinlochewe, and extends for some distance up the bed of the stream, apparently cutting off the quartzite from the newer group. This rock is called diorite by Nicol, syenite by Murchison, Geikie, and Hicks; it is shown by the last author upon a section‡ as intrusive among the calcareous series which overlies the quartzites.

Almost immediately on reaching the spot where the "syenite" first appears on the floor of Glen Laggan§ I was struck with its gneissic aspect. Without, however, halting for long, I walked up the bed of the valley for about two miles, examining the rocks as I went, and found this gneissic aspect continued. About 100 yards from a cottage (perhaps three miles from Kinlochewe) there was indubitable gneiss, the foliation dipping to about W. 30° S.‖ Near the junction of the two upper branches of the glen I climbed up the right bank for about 300 ft., and found clearly marked foliation, dipping at 25° to about S.E.; and about 50 ft. above this a well-banded gneiss occurs, dipping 30° to about E. Still higher up I found a sharper dip, rather to E.S.E.¶

* Vol. vi. No. 2.

† Published vol. xxxiv. p. 811.

‡ Q. J. G. S. xxxiv. p. 814.

§ Glen Cruchalie of Murchison.

‖ The readings were made with a pocket compass, subsequently corrected to true.

¶ It may be well to mention that I am perfectly aware (see my paper Q. J. G. S. vol. xxxiii. p. 893 &c.) that occasionally true igneous rocks exhibit foliation. This possibility was always present to my mind during the examination of the above district; but what I then saw seemed inexplicable in that way.

I then returned to the well-known section at the lower end of this "syenite" *massif*. The stream has cut a shallow but picturesque gorge in the crystalline rock, at the mouth of which the "limestone" is well exposed by the water side. The former rock chiefly consists of a pink felspar and a green micaceous mineral, with variable amounts of quartz and a little epidote. Everywhere its aspect is rather that of a metamorphic than a granitic rock*, the green mineral in most places giving it a foliated structure, which strikes from about W. 20° N. to E. 20° S. in one part, to about N.E. and S.E. in another. This is particularly distinct on the left bank, about 30 yards above the junction with the calcareous series, where the rock is beyond question a rather felspathic gneiss.

On following the "syenite" up the slope of the right bank of the valley we find a green serpentinous-looking schist emerging from beneath it. This, on microscopic examination, proves to be a true schist. It consists of quartz and felspar, with opacite, viridite, and a fibrous chloritic or hornblendic mineral, the amount of the green constituent being less than, from the colour of the rock, one might expect. It exhibits a very marked fragmental structure; but this I strongly suspect to be due to crushing *in situ*†.

The beds of the quartzose and calcareous series near the river dip to about S.S.E. at angles varying roughly from 20° to 30°. Some 100 feet up the slope the angle is 37° S.S.E. Further down the stream the dip changes nearer to E., and there is a roll over. I carefully examined the relations of the "syenite" and of the calcareous series, and could not find that they exhibited any of the ordinary indications of the junction of an intrusive igneous and a sedimentary rock. In most of such cases that I have examined (and they are many), where the former rock is coarsely crystalline, the line of junction is firmly welded and usually found with ease, if a fair surface of rock be exposed. Here, though the two rocks could often be seen almost touching, no contact-specimen could be discovered, and every appearance indicated that the junction is a faulted one. Neither of the rocks changes in mineral character on approaching the boundary; both appear rather crushed‡; and this structure becomes very evident on microscopic examination, one of the specimens appearing singularly like an angular quartz-felspar grit§. After much careful

* I do not refer here to foliation only, but a peculiar indefiniteness in the outlines of the crystalline constituents and other characters.

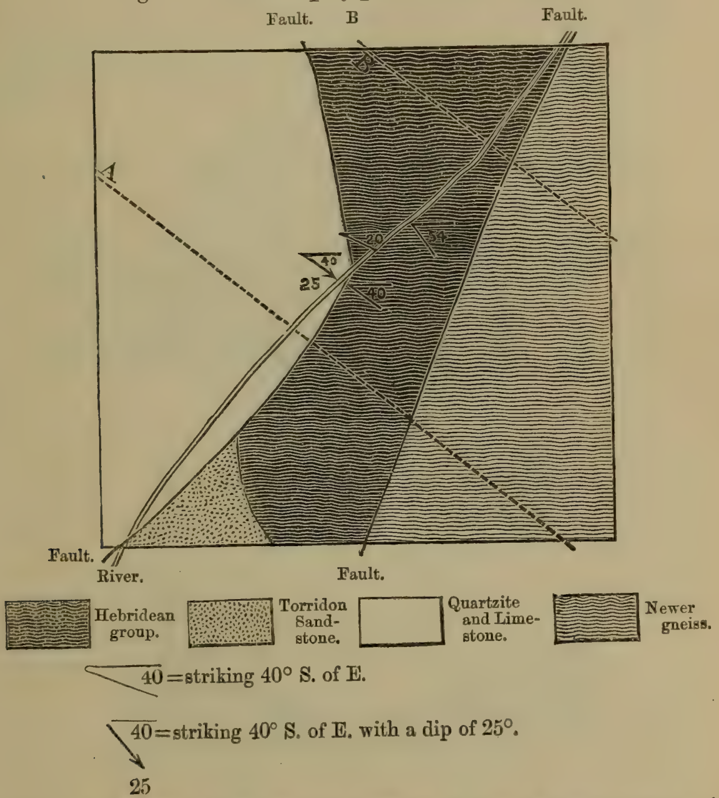
† Roughly on the strike of the above, and higher up the hill, a rather schisty grey rock appears to be overlain by the "syenite." There is, however, nothing incompatible with this being a member of the newer series (which microscopically it resembles more than the older) locally nipped by the latter. So that I do not think this one very dubious case sufficient to shake the body of evidence in favour of the non-intrusive character of the "syenite."

‡ The "syenite" is evidently much shattered, and is cut by numerous veins with quartz, felspar, epidote, &c.

§ It is obvious that this structure (very visible in three specimens, selected from near the line of junction) presents to upholders of an igneous origin for the "syenite" the following dilemma:—If it is not the result of crushing, but an original structure, *cadit quæstio*; if it is, then it is a most exceptional structure to be found near an igneous junction.

consideration of the question, I have no hesitation in asserting that all the so-called syenite (except some intrusive dykes) is simply a rather granitoid variety of the Hebridean gneiss, and that its junction with the calcareous series is a faulted one. The fault descends the right bank of the valley, striking about E.S.E., changes its direction before reaching the river to a little E. of S., and while crossing it appears to change again, and emerge, striking about midway between S.W. and S.S.W. (fig. 1). Here also the Hebridean gneiss can be

Fig. 1.—*Sketch map of part of Glen Laggan.*



followed along the hill-side, and traced to within a short distance of the newer series; but I could not, though I searched carefully, find an actual junction. On this side also I observed a case of very distinct foliation in the "syenite," dipping at about 45° to S. 20° W. Below this spot the ordinary Hebridean gneiss can be traced by the river-side at intervals, obviously forming part of the same series, to a sheep-fold at the mouth of the glen. It is overlain by Torridon Sandstone, which occupies, I believe, all the undulating shoulder between the streams from Glen Laggan and Glen Docherty, except that in two places the "quartzite" series crosses for a short space over to this left bank of the former valley.

We have thus a very irregular slip of Hebridean gneiss, capped in part by some Torridon Sandstone, bounded by two or more faults, which bring down the quartzite and calcareous series on the one hand and the newer gneiss series on the other (figs. 2 & 3)*.

In the section given by Sir R. Murchison (Q. J. G. S. vol. xvii. p. 191) a small patch of "syenite" is also marked as occurring on the right bank of Loch Maree, near its head. Of the gneissose character of this I have not any doubt; but I also found there a rock which, both macroscopically and microscopically, appears to be a true diorite. I saw no signs of intrusion, and think the presence of this patch of the older rock may be explained by faulting, though I am not prepared at present to say in what manner that is to be connected with the other faults.

Fig. 2.—*Section in Glen Laggan along the line* A *in fig.* 1.

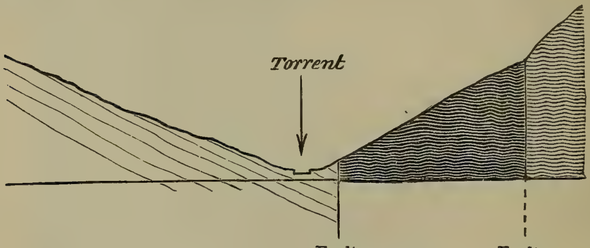
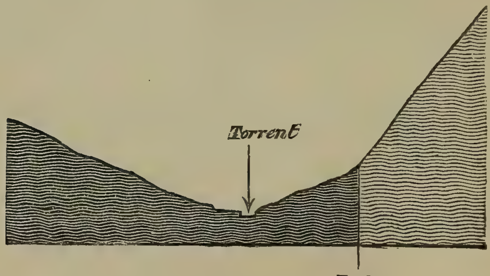


Fig. 3.—*Section in Glen Laggan along the line* B *in fig.* 1.



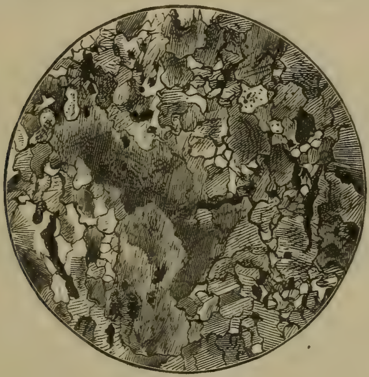
(2) *Hebridean Gneiss, together with the so-called Syenite.*

The macroscopic characters of this rock in the present district have been already described by previous observers, so it will suffice to make a few remarks on the microscopic structure of the specimens which I collected. These were obtained from the above-named localities in Glen Laggan, at intervals on the right bank of Loch

* I had with me a copy of Dr. Hicks's section (vol. xxxiv. p. 814), but entirely failed to reconcile it with what I saw on the ground.

Maree, as far as Ben Slioch, and a little to the north of the Loch-Maree hotel*. They vary considerably, some, as in the Laggan valley, being mainly quartz and felspar, with a little of a green micaceous mineral, others ordinary mica- or hornblende-gneiss, others, again, rather hornblendic or chloritic schists. All, however, exhibit conspicuously that massive structure which early observers rightly fixed upon as characteristic, and, as a rule, are fairly uniform for a considerable vertical thickness. The microscope shows that quartz and felspar are always present, exhibiting the rather irregular granular form characteristic of gneissic as opposed to granitic rocks (fig. 4). The quartz is generally fairly clear,

Fig. 4.—*Hebridean Gneiss from near base of Ben Slioch.*



enclosures or cavities being very minute, though in one or two cases there is a considerable amount of dusty opacite. The felspar, usually more or less decomposed, varies in quantity, rather predominating in the specimens from near the junction in Glen Laggan. These appear to contain microcline; it is, perhaps, present in the others with considerable quantities of plagioclase (probably oligoclase), as well as orthoclase. Epidote microliths and other decomposition products are present largely in some specimens. One of those from Glen Laggan consists almost wholly of quartz and felspar, with a minute quantity of a pale hornblendic(?) mineral, and a little opacite and magnetite, being almost exactly like specimens from North Wales and Shropshire, for which I have proposed the name granitoidite. Another (more gneissic) contains a chloritic mineral and a little pale-coloured mica. A third, macroscopically much greener than the others, appears to owe its colour chiefly to quantities of very minute epidote.

Mica is conspicuously present in two specimens collected by the roadside north of Loch-Maree hotel, in one from the floor of Glen Laggan, some distance up stream above the gorge, and in one collected by the shore of Loch Maree, at the south end of the base of Ben Slioch.

* The third group and most of the second are universally admitted to be the Hebridean gneiss.

In the first three cases the mineral is a green mica, probably an altered biotite; in the last, with a little of the same, we have chiefly a silvery-white mica, showing brilliant tints with polarized light, probably margarodite or paragonite. Hornblende (green) with very characteristic cleavage and strong dichroism is plentiful in the specimens from near the Loch-Maree hotel, in a hornblende schist from near the above-named locality, under Ben Slioch, and in a dark compact schist in the bed of a burn to south of latter. There is also a little in the above Glen-Laggan specimens, and more dubiously in others. Epidote is present in the last, and in numerous well-formed crystals in the first two. Few specimens are quite free from it. Apatite is distinctly present in the first three of the above specimens, and more dubiously in others. One of them ($\frac{3}{4}$ mile from Loch-Maree hotel) contains numerous crystalline grains of a yellow-brown mineral, which I have little doubt is sphene; and the same mineral is present in other specimens. Opacite and grains of iron peroxide, probably magnetite, occur in most in greater or less degree.

Microscopically, then, as well as macroscopically, this group of rocks has well-marked characteristics, which we also find, as we might expect, in the gneiss of the vicinity of Stornoway*. There is also a certain family likeness to the old gneissic rocks of Anglesey, Caernarvonshire, the Wrekin, and the Malvern Hills; and a resemblance may even be noted to specimens from West Greenland and the Lofoten Islands, not to mention yet more distant localities.

(3) *Torridon Sandstone.*

In the case of this rock also we may refer to the careful descriptions of earlier observers. I examined it on both sides of Loch Maree, over the district mentioned above, and at Loch Torridon. Striking instances of the breccia of gneissic rock at its base can be seen by the roadside north of Loch-Maree hotel, and on approaching the base of Ben Slioch on the opposite shore. Commonly the sandstone is fairly uniform in character, a hard grit composed of rolled grains of quartz and red felspar, from $\frac{1}{20}''$ to $\frac{1}{10}''$ in diameter, with a little of a green mineral, being at first sight wonderfully like a fine-grained granite; but now and then it becomes coarse and pebbly—a very pretty variety, with the rolled fragments as big as large peas, occurring in blocks by the road to Gairloch, eight miles from Kinlochewe. Specimens for microscopic examination were selected from the last-named rock, from a spot on the same road nine miles from Kinlochewe, from the lower part of the series (at two levels) on the right bank, near to the base of Ben Slioch, and lastly from the shore near Torridon. With minor differences in detail, their general character is the same. They consist of fragments (usually well rolled) of quartz, felspar, and an altered quartzose rock, in a fine granular matrix, in which some secondary products have been formed. The quartz is generally rather full of minute dusty-looking microliths. The felspar is often infiltrated with ferrite, which in some cases brings out clearly the cleavage-

* The only other locality where I have had opportunity of studying it in the field.

planes. Orthoclase, microcline (often fairly abundant), and plagioclase (? oligoclase) can be recognized. Characteristic crystals of the last are not very common. The quartzose fragments are sometimes either a highly altered quartzite or bits from stratulæ of this nature in a gneiss; certain of them (especially in the specimens from Torridon) have a schistose structure*. There are also a few fragments resembling a rather decomposed fine-grained slaty rock. I am not able to detect any indubitably fragmental mica or hornblende, and must be content to call the green mineral which is sparingly present in the matrix, and almost certainly a secondary product, by the vague term viridite. This matrix resembles a very fine sandy mud, generally much stained with ferrite and rather altered. The change is most conspicuous in the second of the above specimens, which was selected because it had a more marked appearance of alteration than was usual.

(4) *The Quartzite.*

I again refer to the works of earlier observers for the macroscopic characters of this rock. As its variations in this district appear unimportant, I have only examined two specimens, one from the right bank of Loch Maree, a typical example of the pure white variety so abundant on both sides of the head of that lake, the other a slightly yellower and more granular quartzite from the Gairloch road, about three miles from Kinlochewe. The first is composed chiefly of quartz grains, rather irregular in size and form, containing a fair amount of microscopic "dust," and with a minute quantity of ferrite now and then interspersed. The edges of the quartz grains are commonly "fused" together, as is usual in highly altered quartzites, the one being irregularly indented into the other, as if the two had been pressed together when in a slightly viscous condition. A few small fragments of felspar can be recognized, resembling that in the last series. Cracks traverse the slide, filled apparently with minute fragments of the rock itself, cemented by secondary quartz, perhaps indicating local crushing of the mass. In the other specimen the only difference worthy of note is that the grains are a little larger in size and more irregular in shape; that no felspar can be recognized, though an earthy dark-stained mineral, generally torn away in grinding, probably indicates that it has been present; and there are little scattered clots of ferrite, and a few specks of a pale hornblendic mineral†. A slice from the "fucoidal" quartzite has also been examined. Except that there is more fine silty matter among the quartz grains, there

* I have examined microscopically a fragment from a block (perhaps 2 cubic feet) in a remarkable breccia north of the Loch-Maree hotel. It consists mainly of quartz, in rather minute grains, with occasionally larger grains (of very irregular outline) of felspar, with wavy microliths interbanded, scales of iron glance, a fair quantity of epidote, and a little white mica. It is therefore a highly altered schisty felspathic quartzite.

† I did not examine into the disputed question of the conformity or unconformity of the quartzites and Torridon Sandstone; the general appearance of the two suggests the latter, as maintained by Sir R. Murchison; but my friend Mr. L. Ewbank, Fellow of Clare College, tells me that near Dundonnel (Little

is nothing special to note. Some at least of the "fucoidal" markings are probably Annelid-tubes; one has been cut through in this slice, but nothing special is shown.

My work, I may be allowed to mention, fully confirms the opinion that the quartzites of the Bunter pebble-beds of the Midland Counties have been derived originally from these quartzites of North-west Scotland. I have been familiar with the Bunter pebbles of Staffordshire all my life (being a native of that county), and could not separate some of them from certain of the varieties which I saw in the neighbourhood of Loch Maree. Further, I have recently examined two of these pebbles microscopically, and find also in them occasional indications of wavy-banded and cross-hatched felspars. I have also identified them in conglomerates of Old Red Sandstone and Lower Carboniferous age in the more southern parts of Scotland, notably in the sandstones near Brodick, Arran.

(5) *The Calcareous Series.*

Dr. Hicks* lays some stress upon the separation of the strata in the bed of the stream by the gorge of Glen Laggan ("blue flags, sandstones," &c.) from those seen higher up on the right bank ("limestones, calcareous sandstones," &c.). It seems to me, however, that it is simpler to regard them as one series, continuous with the quartzites below, but much more variable in mineral character, and so in the amount of change which has been produced in them. To my eye they exhibited no signs of increased alteration in the neighbourhood of the "syenite." I have examined only one specimen microscopically, from the immediate neighbourhood of the latter rock. It is a rather muddy-looking crystalline limestone, to some extent dolomitic, as I suspect, greatly crushed and recemented, in part by infiltrated quartz. No traces of organic structure can be found; and from the aspect of the slide I doubt whether such are likely to have escaped obliteration, if ever they were present.

(6) *The Newer Gneiss.*

This series, as we have said, is brought into close juxtaposition with the older gneiss in Glen Laggan. Here it forms a well-marked escarpment, which, directly below the gorge, trends towards the S.W., and passes on behind the shoulder occupied by Torridon Sandstone to the mouth of Glen Docherty, forming a continuous cliff, which, on the right bank of that valley, is of considerable elevation. A fault passes down the bed of Glen Docherty, shifting this newer series and its escarpment to the northward, so that it is exposed on the left bank of the river, near Kinlochewe Lodge, and, further, by the side of the

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Loch Broom) he traced a gradual passage from the one to the other. A fallen block which I found near the commencement of the quartzite, on the right bank of Loch Maree, certainly appeared, macroscopically and microscopically, intermediate between the two; the break, therefore, is probably rather local than general.

* Q. J. G. S. vol. xxxiv. p. 813.

Garrie, within a very short distance of the hotel*. The views as to the relations of this series to the other rocks are concisely stated by Dr. Hicks†, in speaking of the Glen-Laggan section, as follows:—"Prof. Nicol places a fault at this point, and says that the fundamental gneiss is here brought up to give it an appearance of overlying conformably the unaltered series. I, however, hold, with Sir R. Murchison and Mr. Geikie, that the next is a younger series, and that it overlies the unaltered beds; but I entirely demur to the view held by them that the rocks which compose this group, as exhibited here, should be called gneiss rocks, or associated in any way with those which have undergone the metamorphic change so characteristic of the pre-Cambrian rocks as known in this country, and which could only be induced, I believe, by influences to which it is evident these rocks, as shown by their position and undisturbed state, could not have been subjected, and which would occur mainly during periods of great depression combined with heat, moisture, and pressure. On examination I found these upper beds everywhere unaltered, except near dykes, and the change there induced in them was that now well known as partial or contact-alteration, and which is so entirely distinct from true or general metamorphism. These beds all dip to the S.E. at a low angle, and attain a thickness of several thousand feet. They are flag-like in character, and are made up chiefly of fragmentary materials, but are occasionally slightly calcareous. They are much like some of the Lower Silurian flags in Wales, and are in no degree more highly altered than many of those rocks in the more disturbed districts." He goes on to state that, in his opinion, the lower rocks exposed by lateral streams on the north side of Glen Docherty are very unlike those along the hill-side at the higher levels. "They were evidently much more allied to the gneiss of the west side of Loch Maree; and the strike proves to be, as in the latter, from N.W. to S.E., and hence in an entirely opposite direction to that in the higher beds. . . . . These gneiss rocks keep at a low horizon for about four miles, or until we reach the top of the Glyn. At this place they assume a reddish granitoid appearance, and ascend considerably higher into the hill. For the next few miles they are traced with more difficulty, and probably faulted, but rise up again into the mountains as we approach Auchnasheen. The upper or overlying beds are entirely lost at the ravine which separates these hills from Ben Fyn and the range of mountains behind Auchnasheen."

One difficulty, inherent in this view, cannot, I think, fail to strike the observer as soon as he has become familiar with the district. It is the disappearance in so short a space of the entire thickness of the Torridon Sandstone and the quartzites, not to mention the overlying calcareous series. These, at the southern end of Loch Maree, can

* Here the dip is 8° to S.S.E.; about ¼ of a mile higher up the stream 26° to S. The Glen-Laggan fault is prolonged up Glen Garrie, the quartzite still plunging towards it, but its throw is diminished. It is remarkable in this district how closely the streams follow the faults.

† Q. J. G. S. vol. xxxiv. p. 814.

hardly be less than 3000 feet in thickness. The rock is sufficiently exposed in the cliffs on the right bank of Glen Docherty to enable us to see if they comprise any representative of these strongly marked and peculiar beds. Much there could not be; for there is not room for any great thickness between the admitted upper and the asserted lower series. Not a trace is visible. Three thousand feet in three miles! surely this is an unconformity which we could only accept on the clearest and strongest evidence.

This evidence is, I fear, wanting. First, I cannot admit the accuracy of Dr. Hicks's statement about the unaltered condition of the beds of the newer series in Glen Laggan. I examined them on the ground with great care, and came to the conclusion that though their flaggy character is very marked, they are rightly classed with the metamorphic rocks, consisting, among others, of dark green, rather compact schists, soft dull-coloured mica-schists, and micaceous quartzites. In the cliff between Glen Docherty and Glen Garrie the "metamorphic" character of the rocks is more conspicuous; and I cannot conceive it possible to call the beds exposed by the two streams, at the entrance of Kinlochewe hamlet, any thing else than schists; yet that they are part of the same series it is impossible to doubt. Typical specimens were selected for microscopic examination—two from the face of the cliff in Glen Laggan (*a*, *b*), two from the abovenamed cliff between Glen Docherty and Glen Garrie (*c*, *d*), and one from the left bank of the river, just to the east of Kinlochewe (*e*).

Of the Glen-Laggan specimens, (*a*) was chosen from a compact dark green rock, (*b*) from a brownish-grey compact quartzose rock, with some minute spangles of silvery mica. Both rocks are very "flaggy," the former, on close inspection, showing a distinct though minute foliation parallel to bedding (fig. 5); the latter is less distinctly foliated,

Fig. 5.—*Micaceous Schist of the Newer Series, Glen Laggan.*

but obviously altered. The microscope shows them to consist chiefly of quartz and a micaceous mineral, with a fair amount of felspar, some epidote, &c. Minute grains of quartz, as it were agglutinated together, compose the greater part of the slide, with the micaceous mineral, both disseminated and in wavy bands, parallel with the stratification. In this ground-mass are scattered larger subangular grains, lying generally lengthwise, with the mica scales bending round them, so that they form, as it were, "eyes" to the slide. Most of them are felspar, many are plagioclase*, one or two probably microcline. The micaceous constituent is rather fibrous, moderately dichroic, showing bright colours with the two Nicols, and is uniaxial or orthorhombic—probably a hydrous magnesia-mica; but there may be more than one mineral present—many small grains of epidote, a fair number of iron oxide, probably hæmatite, and a little calcite in (*a*). These rocks appear to me beyond question metamorphic in the full sense of the term, though very distinct from, and not so extremely altered as, the Hebridean series; for the quartz is wholly unlike that in any sandstone, however indurated, and the mica appears to have crystallized *in situ*. Specimens (*c*, *d*) resemble respectively the two from Glen Laggan, but are a little more micaceous; the microscope shows the differences to be merely varietal. The only difference noteworthy in the specimen (*e*) is that it is chiefly quartz and mica; the latter is in larger scales, and there is certainly another minute green mineral with it, showing strong dichroism, possibly a chlorite†.

Proceeding up Glen Docherty, by the road which follows the right bank of the stream, we pass, after the spot named above, the shoulder of Torridon Sandstone, and then ascend the glen with the newer series on both sides. At first not much rock is seen *in situ* by the road; what there is appears to belong to this series. At nearly $2\frac{3}{4}$ and 3 miles from Kinlochewe are slopes of screes derived evidently from the cliffs high above the road, which indubitably consist mainly of fine quartzose gneisses, foliated, as before, parallel to the flaggy bedding. Higher up, rock is frequently exposed by the road, but it is all of a similar character. The most highly altered is a lead-coloured mica-schist, which, higher up, is exposed in a little lateral ravine. This, however, is totally different from any member of the Hebridean series, splitting with comparative facility, and pulverizing under the hammer. Moreover, it is overlain conformably by a flaggy quartz-schist, just like those already described. This, or a bed nearly at same level, reappears in a cutting where the road enters the open moorland at the head of Glen Docherty, rather more than $3\frac{1}{2}$ miles from Kinlochewe. I have examined both rocks microscopically. The former differs from those already described only in having more mica and a rather more marked schistose structure (fig. 6). There are certainly two species of mica, one colourless, the other an altered biotite, rather more altered (and decomposed) felspar, and some small, imperfectly formed garnets. The overlying rock is a

* The results of the optical tests vary so much that I cannot attempt to name the species; some agree with labradorite, some rather oligoclase.

† I have a suspicion it is uniaxial. The above slides, I may mention, have been shown to Prof. Renard and Prof. Morris, both of whom agree with me as to the true metamorphic character of the rocks.

kind of gneiss, with a structure generally resembling the quartz-schists described below, but containing a little more felspar (decomposed). The difference, however, is simply varietal.

Fig. 6.—*Mica-schist from the upper part of Glen Docherty (Newer Series of Author).*

It is quite true that the mica-schists in the road dip (at about 30°) a little W. by S., and that in the ravine about to S.W. The dip of the gneissic rock a little above is nearer to the former; but on the opposite side of the glen the rocks appear to preserve the usual south-easterly dip; and these quartzose beds have a very shattered aspect; so that I have not the slightest doubt the change of strike is merely local, and due to the neighbouring fault, as in the case already described.

Between this point and Auchnasheen little rock is exposed near the road, but nothing in the *terrain* suggests the introduction of any group other than that from which Glen Docherty is excavated. From Auchnasheen I ascended Ben Fyn, mounting by the right hand one of two streams visible from the inn, and returning (in part) by the other. A small quarry, about 200 ft. above the inn, gives a good section of a gneiss with red garnets. The rock is flaggy in structure, well foliated parallel to its bedding, dipping towards the E. at about 30° (rather rolled), having a general resemblance to the newer series to the north-west, but more highly altered. Under the microscope the rock is seen to consist of quartz, clear (with exception of some small microliths and very minute cavities), orthoclase felspar, with some plagioclase in good preservation (long colourless belonites are present in some of the crystals), biotite and a little of the white mica already described, and opacite, with two or three garnets. The rock is more highly altered than the rocks already described, but still presents some structural resemblance to them*. Above this for some 1200 ft. the rocks continue to be flaggy, occasionally most conspicuously, but

* Some of the grains show a minute "graphic" or, rather, vermicular structure. *Cf.* 'Nature,' xiv. pp. 8, 68.

always gneissic, sometimes more, sometimes less micaceous, this mineral occasionally predominating. At 750 ft. is a quartzose gneiss, very like those noticed in the series in Glen Docherty, and, microscopically, nearly related to the quartz schists at the top of that glen and on the cliff above Kinlochewe. On a shoulder at 1470 ft. micaceous schist (dip about 45° S.); at 1830 ft. garnetiferous gneiss (dip almost vertical, apparently to a little S. of W.). At 1900 ft. is an intrusion of garnetiferous diorite; its felspar is much decomposed, and the hornblende projects from the weathered surface like the augite in the gabbro of Skye. The garnets are sometimes as large as small cherries. There appear to be two bosses of it, of irregular form and possibly connected. The adjoining micaceous gneiss is locally twisted and disturbed.

I continued the ascent to the edge of the corrie on the eastern face of the mountain, and turned back (it being needless for my purpose to proceed further) at a height of about 2480 ft. above Auchnasheen. Over the upper part of the hill the dip of the gneiss is generally high. Though lithologically similar to that in the lower part, it is less distinctly flaggy, and the coincidence between bedding and foliation is less conspicuous. After careful search I failed to find any hornblendic rock other than intrusive, and am certain that nothing resembling the Hebridean series of Loch Maree could occur in the comparatively short space between the spot where I stopped and the summit. The strike of the rocks cannot be pressed too far as evidence, for it is very variable. My notes include various points, from nearly due N. to nearly due W. While travelling by a slow train to Dingwall, I observed that the rocks as far as Strathpeffer were flaggy gneisses, generally similar to those above described—a coarser variety, with large scales of white mica, occurring near the latter place.

(7) *Igneous Rocks.*

There are compact greenstone dykes, as already said, in Glen Laggan, cutting the Hebridean series. One of them, on the left bank, a little below the gorge, I have examined; but it has been so much altered that it is difficult to give a good account of it. The felspar (probably plagioclastic) has been largely replaced by minute pseudomorphs. There is some dark-brown mica and pale-green hornblende (probably a secondary product), and what look like diallage or augite crystals, replaced by ferrite, opacite, viridite, and earthy-looking matter. Near the head of Loch Maree (right bank) I collected a massive hornblendic rock, which appears on examination to be a diorite, though the structure is obscured by decomposition. There are two varieties of hornblende and many small garnets. The diorite of Ben Fyn consists chiefly of hornblende and red garnet; the former mineral is green and strongly dichroic, rather irregular in outline, with characteristic cleavage. It contains many rather large microliths, in some of which may be seen a small crystal of magnetite or some opaque mineral. Most are roundish in section, one or two hexagonal, doubtless quartz. The garnet contains numerous minute belonites, as well as enclosures similar to the last in less number, and microliths of hornblende (?). There are clustered grains of a mineral rather resembling sphene, which also occurs in separate crystals*. There is also quartz, with hornblende (?) microliths, plagioclase felspar, and possibly a little zircon. The slide, of necessity, has been cut rather thick, so it is difficult to be certain of some of the microliths. From the above description it will appear that the rock might be named a hornblende-eclogite.

The bearing of the evidence of this district upon general questions of metamorphism is highly interesting and important. Above the comparatively unaltered Torridon Sandstones we have, as all allow, the highly altered quartzite. Above the seemingly unaltered limestone series we have the true schists of the upper group, which also become more highly metamorphosed as they are traced towards the south-east. The possibility of the latter change will probably be more readily admitted, as it might be explained by deeper entombment under superincumbent strata, or nearer approach to regions of elevated temperature, of which indications are given by the great granitic masses of the Central Highlands. But how are we to explain this alternation of metamorphism in a vertical direction? It shows, I think, how important the mineral constituents of the bed and their mode of association are as factors in the general result. In the Torridon Sandstone well-rolled grains of moderate size occur in a matrix, scanty indeed, but commonly just enough to separate them. In the quartzite clear and perhaps rather less-rounded quartz grains are in apposition. The latter have become agglutinated; and the same result may be seen to have happened in the former, where two "clean" grains are in contact; but the interposition of a little "dirt," as we may sometimes see in the quartzite, is an obstacle to union†. Felspar grains seem to unite less readily. The amount of mineral change in the matrix seems to depend on both its constitution, if homogeneous, and mode of association, if not. If, for example, it contains the constituents of viridite or epidote in a right state of division, these minerals are readily formed; if not, change is slow.

The muddy beds overlying the quartzite appear to have resisted change, other than the formation of crystallized calcite (and perhaps dolomite). The series above these, however, has been of a more favourable composition; and in it we see bed differing from bed in the amount of metamorphism. But into these interesting questions I must abstain from entering. I trust some day, when I have added yet more to the large quantity of material which I have been for some time past collecting, to invite the attention of the Society to

* Since the above was written, Prof. Renard has seen the slide, and was of opinion that this mineral was more probably staurolite. Some of it certainly suggests that the mineral is orthorhombic; but unfortunately no crystal that I can discover in the slide gives quite conclusive evidence.

† Of this the preservation of Annelid-tubes in the quartzite is a marked instance. These certainly occur occasionally, so that we need not here refer to the so-called fucoidal markings.

this most interesting question of the nature of mineral change in metamorphic rocks, and the traces which they may have preserved of their original structure.

From the above observations it results that I am unable to recognize any marked similarity between the Hebridean series about the upper part of Loch Maree and the beds which are seen on Ben Fyn and in the upper part of Glen Docherty; while both microscopic and stratigraphic evidence, as I read them, point to the identity of the latter with the beds exposed in the northern escarpment of the newer series. In this series the effect of metamorphism varies in degree, as we have already shown, and increases in amount as we advance towards the Central Highlands; but the peculiar flaggy character of the strata (long since pointed out by the late Sir R. Murchison) is retained; and there is no resemblance, in any important point, to the older series. It appears, then, to me that, so far as the neighbourhood of Loch Maree is concerned, the views advocated by that distinguished geologist and his fellow-labourer Prof. Geikie are fully confirmed by microscopic evidence.

Discussion.

Dr. Hicks stated that he had studied the district under the most favourable conditions of weather, and had measured the section foot by foot. The rock regarded by Prof. Bonney as gneiss was so regarded at first by Macculloch and Hay Cunningham; but they saw ground for changing that opinion, and believing that it was intrusive, in which they were confirmed by Nicol, Murchison, and Geikie. It also cuts *across* the beds of the older gneiss, as shown even in Prof. Bonney's diagram and map. He maintained that the reading of the section in Glen Laggan which he had already given is the true one. He objected to the diagrammatic nature of Prof. Bonney's sections. He insisted on the exact agreement between the rocks of Ben Fyn and those of Gairloch, and their distinctness from the micaceous flagstones of the younger series. He pointed out that the strikes of the several rocks do not bear out Prof. Bonney's views. The N.W. strike of the lower rocks in Glen Docherty is most marked; and this, with the high dip and difference in the characters of the rocks, proved conclusively to his mind that the micaceous flags of the upper series, with a N.E. strike and low dip, rest here on a floor of the old or western gneiss.

Mr. Hudleston had examined the district with the advantage of Dr. Hicks's sections and descriptions. He came to a conclusion opposed to that of Dr. Hicks and agreeing with that of Prof. Bonney. He was entirely opposed to Dr. Hicks's views concerning the section in Glen Docherty. He demurred to the importance which Dr. Hicks attached to the differences of strike among the gneisses. He regarded the section at Loch Maree as by no means suitable to serve as a typical one.

Mr. Rutley had seen structure like that in the metamorphic rock described by Prof. Bonney in artificially altered sandstones.

Mr. Blake argued on general grounds against the correctness of the section given by Dr. Hicks.

Prof. Seeley had not examined the country with a view to deciding between the contending views. He insisted on the great variability of the rocks.

Prof. Bonney insisted that the map which Dr. Hicks relied upon was very inaccurate. Prof. Morris quite agreed with him as to the evidence derived from the microscopic sections. He insisted on the necessity of greater accuracy than Dr. Hicks had shown in fixing the locality of his specimens. He was quite content to await the judgment of future observers as to the accuracy of the views which he was maintaining.

9. *On an apparently* New Mineral *occurring in the* Rocks *of* Invernessshire. By William Jolly, Esq., F.R.S.E., H.M. Inspector of Schools, Inverness, and J. Macdonald Cameron, Esq., Fellow Inst. Chem., F.C.S., of the Chemical Laboratories, South Kensington Museum. (Read June 11, 1879.)

(Communicated by Prof. J. W. Judd, F.R.S., Sec. G.S.)

[Abstract.]

I. Its Geological and Geographical Distribution.

The Moray Firth, from Duncansbay Head to Buckie, is enclosed by the Old Red Sandstone, except some Jurassic patches near Brora and Cromarty, and others near Elgin. In this area it is touched by no Silurian except for a few miles between Inverness and Beauly. The Old Red Conglomerate and other beds exist west of Inverness in a triangular patch between Dochgarroch and Bunchrew. The Silurian to the west of this forms an oblong semidetached area surrounded by Old Red, except for a few miles on the south. This Silurian patch has a general slope to the Moray Firth on the north, into which it is drained. Its main stream is the Moniack Burn, rising three miles north of Drumnadrochit in Glenurquhart, running generally along its centre and falling into the sea west of Lentran. The strata form a syncline, the axis striking roughly N. and S., the rocks on the east dipping to N.W., those on the west dipping generally to S.E., but the latter much disturbed. They consist chiefly of clay-slate, micaceous and chloritic schist, and gneiss.

A limestone, worked at several points, runs parallel to and near the axis, of varying thickness, sometimes twelve feet, and often concretionary and interbedded with other rocks. A red granite also occurs in the Silurian near Abriachan; it is of commercial value, and known as Loch-Ness granite.

Within this Silurian area the mineral which was the subject of the paper occurs at five points, at three of these *in situ*, and has as yet been found nowhere else. It is of a blue colour of various shades, from ultramarine to bluish white, often striking and beautiful. It occurs generally in a felspathic matrix, readily disintegrates under water to a fine, blue, soapy, unctuous clay (caused probably by the magnesia it contains), and is seldom found pure, and never yet in a crystalline form, though it sometimes presents a glistening crystalline aspect. The sites where it has been found are these:—

(1) *Englishton Moor.*—On the west side of Bunchrew Burn, a little above the Public School of Kirkton, at No. 23 croft, near an outcrop of limestone. It occurs here only in scattered blocks evidently carried from the west at Moniack Burn, where it is *in situ*. It is chiefly found in thin veins and plates in felspar. It was here that the mineral first attracted special attention, during an excursion of the Scientific Society and Field Club of Inverness, on September 1st,

1877, at which both the authors were present—Mr. Jolly having previously noted it in a preliminary examination of the ground along with Mr. Cran, of Kirkton, and Mr. Cameron having, at the excursion first suspected its rarity and subsequently analyzed it.

(2) *Moniack Burn.*—This passes through a very picturesque gorge called Reelig Glen, enclosed by high cliffs, finely wooded, and attractive to the geologist and botanist. The stream runs here along a fault, near the synclinal axis, associated with a remarkable conglomerate and with granitic, felspathic veins. A great fall of rock took place last winter from the face of a high precipice in the glen above Reelig House. The fallen débris contained much of the mineral, associated with orthoclastic felspathic rock, interbedded with clay-slate, and mica and chloritic schist, &c., not only in veins but in regular strata some feet in thickness.

(3) *Near South Clunes Farm.*—It is also found *in situ* above this gorge, on the east bank of the stream, at a limestone-quarry, where it occurs in great purity in a felspathic rock in contact and bedded with the limestone. It seems here to be more or less associated with the limestone, which crosses the river from this point near the fallen cliff, and runs to Rebeg farm, where also it is worked.

(4) *Near Dochfour, at the north end of Loch Ness.*—It occurs here in rock *in situ*, on a new road to the Mansion House, about 150 yards north of a new bridge over Dochfour Burn. It is also associated here with felspar in large masses, bright blue at first but gradually losing colour by exposure, and easily disintegrating under water.

(5) *At Lochend, at the north end of Loch Ness.*—It was found here, *not in situ*, but in detached blocks in the burn near Lochend Hotel, by Dr. Aitken and Mr. Wallace, members of the Inverness Field Club. The blocks have probably come down the burn, but their source has not yet been discovered.

II. Its Chemical Analysis.

The fragmentary blocks of orthoclastic felspar intermingled with quartz and granite found scattered over Englishton Moor contain the blue mineral in very thin veins or laminæ. The first portions submitted to analysis were from that locality, as it was here attention was first directed to it, and, at the time the first analyses were made, this was the only place where it had been noticed in any great quantity.

As it is unnecessary to dwell on the methods adopted for identifying and quantitatively estimating the several substances entering into the composition of this interesting mineral, we shall simply give the following figures, which are the mean of several analyses of specimens from different localities, and constitute the data from which we have calculated the formula.

	per cent.
Silica	55·02
Alumina	3·37
Ferric oxide	19·03
Ferrous oxide	3·83
Calcic oxide	2·53
Magnesic oxide	12·95
Sodic oxide	1·74
Phosphoric oxide	·33
Loss on ignition	1·45
	100·25

These data point to $\ddot{\mathrm{Si}}_3\,\dddot{\mathrm{R}}\,\dot{\mathrm{R}}_3$, or $\ddot{\mathrm{Si}}_3\,(\frac{1}{2}\dddot{\mathrm{R}}+\frac{1}{2}\dot{\mathrm{R}}_3)$ as the formula for the mineral, and show it to belong to the bisilicate species, the oxygen-ratio for the bases and silica of this species being as 1 : 2, and the general formula $\dot{\mathrm{R}}\,\ddot{\mathrm{Si}}_2$, or $\ddot{\mathrm{Si}}_3\,(\frac{1}{2}\dddot{\mathrm{R}},\ \dot{\mathrm{R}}_3)$, although, so far as we are aware, it is not identical with any known member of this series.

The general formula $\ddot{\mathrm{Si}}_3\,(\frac{1}{2}\dddot{\mathrm{R}},\ \frac{1}{2}\dot{\mathrm{R}}_3)$ would seem to point to its relation to ægirite, a member of the amphibole group. In colour and general appearance, however, it more resembles crocidolite, a member of the amphibole subgroup, though there is no satisfactory agreement between the analysis of the last-mentioned mineral and that of the subject of this memoir.

If we suppose that in the formula $\ddot{\mathrm{Si}}_3\,(\frac{1}{2}\dddot{\mathrm{R}},\ \frac{1}{2}\dot{\mathrm{R}}_3)\ 3\dot{\mathrm{R}}_3=\dot{\mathrm{M}}\mathrm{g}_2+\mathrm{Fe}$, and that $\dddot{\mathrm{R}}$ represents a molecule of the sesquioxide of iron, and keeping in view that the monoxide group, lime, magnesia, soda, and ferrous oxide are mutually replaceable, the above figures point to 6 SiO_2, Fe_2O_3, FeO, 2 MgO as the formula of the mineral.

Properties:—Soft blue amorphous substance, sp. gr. 2·01, unacted upon by acids except when in contact with them for some time. On ignition it changes to a light-brownish powder. Between the poles of a battery it fuses to a metallic bead slightly magnetic.

In conclusion, we thank Professor Frankland for permitting the analyses to be performed in his laboratory, Professor Judd for valuable hints received, and Messrs. Linnell and Shilton for assistance in preparing and analyzing some of the specimens.

Discussion.

Prof. Maskelyne expressed a hope that purer specimens would be obtained, and praised the authors for the discretion and caution they had exercised in not giving a new name to this substance.

10. *On the* Probable Temperature *of the* Primordial Ocean *of our* Globe. By Robert Mallet, Esq., F.R.S., F.G.S. (Read November 5, 1879.)

So far as my reading has extended, I am not aware that any author on physical geology or terrestrial physics has expressed any definite views as to the temperature of the primordial ocean—that is, of the large body of water which, as now collected together, fills the existing basin of the seas and great oceans, the configuration of which, like that of the surrounding continents, has, perhaps, not very largely changed during what is called geological time. Some very vague and indefinite notions may, indeed, be found in the writings of the early and long-since obsolete cosmogonic authors to the effect that the primordial ocean was probably at some indefinite period, and to some indefinite extent, warmer than the sea as existing within the period of human history; but no attempt to assign its temperature at any epoch anterior to our own has, to my knowledge, yet been made. Nevertheless it seems to me that, on grounds of very high probability deducible from admittedly physical laws, we can approach this problem with a facility and certainty of result greater than those which can be obtained in reference to many physical questions smaller in extent and apparently nearer our reach.

According to the calculations of Mr. Gardner, the extent of land is about 37,673,000 square British miles, leaving out of consideration the Victoria continent, and that of the sea 110,849,000 square miles. That this cannot be regarded as furnishing the true proportion of land and water is evident, as there is still, according to Gardner, an Arctic unexplored area of 7,620,000 square miles, and the Antarctic unexplored surface is of vastly greater extent.

An accurate knowledge of the mean depth of the ocean is equally necessary to enable us to calculate the actual amount of water it contains; but in this respect our information is still more imperfect. We know the depths revealed by certain lines of soundings, and probably the greatest depths of some oceanic abysses, but nothing that can give us even an approximate estimate of the cubic volume even of the oceanic waters of our globe; whilst we are in profound ignorance of the amount of water permanently consolidated into ice and present as fresh water in lakes and rivers.

Previously published calculations of the total volume of water existing on our terraqueous globe have been recently submitted to revision by Dr. Krümmel ('Nature,' Feb. 13, 1879), from whose data I am enabled to make the following deductions. I must not omit to notice, however, that there is no greater certainty in Krümmel's final results than in those previously before the world, dependent, as they are, upon the number which he assumes for the mean depth of the ocean, viz. 1877 fathoms—a number which, however carefully deduced by Dr. Krümmel from a comparison of recent soundings, is still perfectly arbitrary and admits of no verification.

Taking the surface of our globe at 173,289,984 square miles, and the total volume of water upon it, as given by Krümmel, at 238,367,880 cubic miles, this volume of water, if spread uniformly over the globe, would cover it to a depth of 1·383 mile; and taking, not 34 feet in depth as equal to the pressure of one atmosphere, but 36 feet (thus allowing for the diminished density of water at high temperatures), the pressure due to 1·383 mile in depth would, at sea-level, equal a barometric pressure (whether of water or vapour it matters not) of 202·74 atmospheres. We therefore see that this pressure so far transcends the limits of experiment that we cannot even conjecture, in the present state of physical knowledge, the temperature of steam that would correspond to it, or, what is the same thing, we know nothing, even approximately, of the boiling-point of water under such a pressure.

It is matter of common knowledge that, leaving out of view some minor conditions, such as whether the liquid be free from dissolved air, the material of the vessel, capillarity, &c., which slightly vary the result, water boils in an open vessel, the barometer being at 30 inches, at 212° Fahr., or 100° Centigrade; or, in other words, it boils at that temperature under a gaseous pressure which, in round numbers, is equal to that of a column of water of about 34 feet in height.

It is also matter of common knowledge that this boiling-point of water, or of any other liquid, is raised more and more if the liquid be contained in a closed vessel (such as a steam-engine boiler), so that the vapour already expelled may accumulate and its tension continually augment. The boiling-point of any liquid is therefore only that temperature at which vapour is freely expelled from it by ebullition against the pressure, whether elastic or hydrostatic, of surrounding bodies. Situated as we are upon the earth, we can only increase this resistance by boiling water or other liquid in a closed vessel; but could we by any means increase the height of the barometric column which measures the pressure of our atmosphere and of such water-vapour as floats in it, no closed vessel would be necessary; in other words, the entire planet would become the closed vessel, and gravitation alone would perform its function. Thus, for example, could we remove from the ocean's surface a plate of water of such a thickness as would represent a plate covering the whole globe to the depth of about 34 feet, then whether the water therein remained liquid or were in the state of vapour, water in an open vessel would then boil at a greatly increased temperature, due, namely, not to one atmosphere, but to two atmospheres; and this would be true of a second or third such plate of water removed from the ocean and vaporized, the temperature necessary to effect this last being derived from the heated globe itself, and the temperature continually rising with the increase of the weight of vaporized water already in the atmosphere. The relations between temperature and pressure of steam have been experimentally investigated by Regnault, and the results given in a series of memoirs, of an elegance and accuracy not to be surpassed, published in the 'Memoirs of the Academy of Sciences of France.' The experiments were performed by order and at the expense of the French Government; and the results which the memoirs contain remain to the present hour the most accurate information we possess as to the relations between temperature and pressure of aqueous vapour or steam. Regnault's experiments proceeded as far as a steam-pressure of 24 atmospheres; and, by extrapolation and empirical formulæ, the results have been extended up to a pressure of 50 atmospheres or beyond. These formulæ, and the results to which they lead, have not the same authority they seemed at first to possess; for almost nothing was then known as to the change in relation between temperature and pressure at some point of temperature differing with the constitution or chemical character of the evaporating body, which, although suggested long ago by the remarkable experiments of Cagniard de la Tour, attracted but little attention until the publication of Dr. Andrews's researches in our own day, by whom this change in the relation of temperature and pressure has been called the "critical point."

It has been understood that Dr. Andrews has been engaged in endeavouring to ascertain experimentally at what temperature the "critical point" for water is reached. The inquiry is, however, one of great experimental difficulty; and I am not aware that any result has yet been arrived at. Some analogies, though not of a very precise character, suggest the supposition that it may be found at about the temperature of melted zinc, or about 700° Fahr. Even were this the extreme limit of temperature at which liquid water first reached our earth's surface, it would have been exalted enough to have given rise to many remarkable geological phenomena, such as are touched upon further on.

The experiments of Regnault need therefore to be extended, and the extension of his results by calculation to be revised, before we shall be in a position to know with sufficient certainty what would be the temperature of the last portions of water were the ocean boiled dry and all the water in the state of vapour still floating over our globe, or, what is the same thing, what would be the temperature of the water first deposited from such an atmosphere upon the heated earth. While I have thus been able, I hope, to make clear the line of physical argument by which, in general terms, these important deductions have been arrived at, it is plain that precise numerical values cannot be attached to them until we shall have ascertained, approximately at least, the actual volume of water existing upon our globe, and shall also possess experimental information as to the relation between temperature and pressure of steam extending beyond Regnault's limits.

So many circumstances concur in support of the nebular hypothesis, that it seems to deserve rather the title of the nebular theory; but, in whichever light it be viewed, there must have been a time when the surface of our planet was destitute of water, and when all terrestrial water existed as vapour floating as an atmosphere round the dry and heated planet; and unless we assume the altogether improbable notion of successive creations of additional water, the whole of our existing oceans, and all the other water of our globe, must have then hung in vapour above its surface, constituting the chiefly aqueous, but partly aerial, atmosphere of the primordial globe. For want of numerical data, especially those relating to the pressure and corresponding temperature of steam, and what the actual volume of terrestrial and oceanic water was, we are unable to assign what the temperature of our globe then was, though it must have been somewhat higher than that of the atmosphere above it, which was exposed to cooling by radiation into space; and in this state of equilibrium between heat and gravitation the slightest reduction of temperature must have been attended with condensation of vapour, and with the first deposit of liquid water upon our earth. It is not an extravagant supposition, therefore, that the first drops of liquid water which ever rolled upon the surface of our globe were at a temperature possibly equalling that of liquid cast iron. However high must have been the boiling-point of water, while it was all compelled to remain suspended as vapour by the repulsive power of the heated globe itself, this last was then, as now, in process of gradually cooling by loss of heat by radiation into interstellar space. With every such decrement of temperature, watery vapour must have been condensed and precipitated in a liquid state upon the earth's surface; but with every such stage of cooling and condensation less water vapour floated above our globe, and less barometric pressure resulted. Hence the boiling-point, or, what is the same thing, the temperature of liquefaction of the remaining aqueous vapour, and of the liquid water produced by previous condensation, must have receded until, in the course of ages, the temperature of ebullition of water reached what we now find it to be. The boiling ocean-water continued to cool until its temperature, as known in historic time and now, was reached; and to this other and, in some respects, more complex conditions than those to which we have already referred concurred, as we shall presently see. When we attempt to follow out the probable conditions that must have attended the gradual refrigeration by radiation into space of a highly heated globe and a nearly equally heated ocean, we are launched upon a mental voyage where the imagination is often left without any sure guide from reason and known natural laws; still, amid so much obscurity, we can discern some outlines which may be regarded as true.

Upon the aerial conditions in relation to the heat and light derived from the sun through an atmosphere composed almost wholly of steam, I shall only remark that such an atmosphere would be much more oblate in form than our present atmosphere, and also much less penetrable by the solar rays, and would therefore produce far greater vicissitudes, both of light and heat, between summer and winter, than now exist. There would always be, as Buffon long since indicated, a great difference of temperature between the polar and equatorial regions; so that during the later stages of the deposition of water upon our globe ice may have formed in polar seas, while the equatorial ocean was too hot to permit the existence of living organisms. At the same time the conditions of temperature and refrigeration of an ocean so highly heated must have caused oceanic currents of a volume and velocity, and hence of a transporting power for solids, unparalleled in the present condition of our earth. The great difference in temperature between the polar and equatorial regions must have resulted also in torrential rains such as are now unknown.

Taking all these points into consideration, we may regard it as highly probable that at about the epoch when the ocean-bed was filled to nearly its existing level, the breaking up of solid rock-matter then forming the surface of the globe, and its reduction into a detrital state, must have proceeded at a far greater rate than at any anterior or subsequent period of the history of our planet; whilst from the known solvent power of water at high temperatures, and from the tendency that heat and water alone, when left at rest, possess to recompact and unite detrital matter into rocky masses, we may likewise assume that this was also a period of energetic rock-formation. If we consider the enormous masses of detritus which we now find everywhere recompacted into rock, we must admit that the conditions of rain, river, and littoral erosion and transport, as we now witness them, will not account for these evidences of ancient action, however much we may extend the limit of time within which they may have acted.

M. Daubrée has observed the formation of various crystallized minerals in the cavities and fissures of ancient brickwork, by deposition from the warm waters of certain springs in the course of the last 2000 years. The numerous and important observations recorded, chiefly by Cotta, upon the disposition and constitution of the mineral matters now found filling fissures and veins penetrating the earth's crust, seem to indicate that these were originally empty, or filled with molten matter from greater depths below the surface. In either case they seem at first to have been dry, though now filled with mineral matters, generally crystallized, often deposited symmetrically on both sides of the central line of the fissure. The characteristic mineral contents of many veins also alter completely with depth. Hence it seems not improbable that these and other phenomena presented by the contents of fissures and veins may be due to their having become charged with water from the gradually filling ocean-basin at a temperature far exceeding the present boiling-point of 212° Fahr., and containing abundance of mineral matters in solution.

To recapitulate in brief the chief points of the preceding paper. At some remote epoch our globe, highly heated, was devoid of liquid water, all the water belonging to it being suspended as vapour above its surface; and in this state of things the boiling-point of water must have been that due to the barometric pressure of the great volume of water-vapour which formed the immensely greater portion of our earth's atmosphere. Secular cooling, however, continued to take place; and as the temperature of the solid globe and its atmosphere, chiefly of aqueous vapour, was reduced, successive portions of this vapour were condensed into water and deposited in the liquid form, and at a temperature which, in the then state of things, was its boiling-point. The boiling-point of water upon our globe was therefore a maximum when all water was held as vapour in suspension; and as secular cooling proceeded the boiling-point became lower and lower, as the water was divided between the vapour atmosphere still in suspension and the liquid water already condensed and deposited from it; and this continued, the boiling-point constantly receding, and the temperature of the liquid water at its point of deposition continually lowering, until the existing state of things was reached.

So much seems to be to such an extent supported by known physical data that it may be considered certain. To its full establishment in a numerical form we need a more accurate determination of the total volume of water appertaining to our globe, and a sufficient extension of the experimental determination of the relations between temperature and pressure of steam. The few deductions which I have made, rather by way of illustration than as at all systematic, far less as exhaustive of the almost boundless field of inquiry which seems to be opened up by the main propositions of this paper, must be judged of for what they are worth by those who have made themselves acquainted with what I have here ventured to set before them.

Discussion.

The President said he had read the paper with much interest, but thought that Mr. Mallet had overestimated the possible temperature of the first deposited water, though, indeed, we were still ignorant of the critical point for water; still he doubted whether water could exist at a temperature higher than a dull red heat. He thought that the geological action also was overestimated; nevertheless the subject had an important bearing on the structure of some of the most ancient rocks.

Mr. Evans said there was one point which separated this question from the ordinary experiments made on water; in them water was held in a closed vessel; here the heat of the vapour could radiate into free space at a low temperature. Then convection might have caused considerable equalization of temperature before any condensation.

Prof. Prestwich said that the cause introduced by Mr. Mallet would tend rapidly to lower the temperature: if the equator and poles were at different temperatures there would be such rapid air-currents as to equalize the general temperature; also if the temperature were so high in earlier times there would be more metamorphism.

Dr. Hicks said that all we know of the earliest rocks was that they were crystalline, but that the rocks following them had their shells unchanged; so that the cause mentioned by Mr. Mallet could hardly have acted since the very earliest days.

Prof. Bonney asked whether, if the heat were still considerable in Miocene time, as stated by the author, there would not be too great heat for life in (for example) Old Red Sandstone time.

Capt. Galton thought that at the period when the very high temperature, viz. that of molten iron, prevailed, water or watery vapour could not have existed, and that when the cooling process had continued so as to admit of the formation of aqueous vapour and water, the high temperature would still not have admitted of the existence of life; consequently the time at which these elevated temperatures prevailed must have been before the time when geological history began.

Mr. Mallet said he did not suppose any part of the original crust of the globe remained at present visible at the surface. Such geological deductions as were made in his paper were only illustrative, and might be open to question. The epoch at which the phenomena occurred to which his paper referred was long anterior to the existence of either animal or vegetable life upon our globe. Hence the palæontological observations that had been made did not seem to him to apply. What he does affirm as certain is that the method he has indicated, requiring for its data a more extended experimental knowledge of the relations between temperature and pressure in aqueous vapour, and a more exact knowledge of the total volume of water now upon our terraqueous globe, affords the means of determining the temperature of our oceanic water at every period, from that of the primordial ocean to our own day.

11. *Undescribed* Fossil Carnivora *from the* Siválik Hills *in the Collection of the British Museum.* By P. N. Bose, Esq., B.Sc. (Lond.), F.G.S. (Read December 17, 1879.)

[Plate VI.]

Introduction.

The able descriptions by Falconer, supplemented of late by Rütimeyer and Lydekker, have made the Sivālik Ungulates widely known in the scientific world; but the remains of the Carnivora, partly on account of their comparative rarity and, perhaps, partly because they mostly belong to forms which do not strike the imagination so forcibly, have had less attention bestowed on them. As long ago as 1836, Falconer and Cautley described two of the larger forms under the names of *Felis cristata* and *Ursus sivalensis**. The latter was afterwards raised to the rank of a genus, called by Falconer, *Hyænarctos*, evidently in opposition to De Blainville, who, under the designation of *Sivalarctos*, placed it at the head of his new suborder Subursidæ. Subsequently Dr. Falconer described another novel and highly interesting Carnivore under the title of *Euhydriodon sivalensis*. All these descriptions will be found in the first volume of the Palæontological Memoirs †. Owing to the untimely death of Dr. Falconer, science was deprived of the rare advantage of a description of the remaining Carnivora from the pen of that gifted comparative anatomist. Most of them, however, had been figured by Mr. Ford for the 'Fauna Antiqua Sivalensis'‡, but were never published. At the suggestion of Prof. Judd and Mr. Etheridge, I undertook an examination of these; and through the courtesy and liberality of Dr. Woodward, of the Geological Department, every facility was afforded to me for my investigation. I have also to acknowledge my obligations to Mr. Davies, of the Geological Department, whose thorough acquaintance with the fossils was of great service to me; and also to the authorities of the Zoological Department for the loan of specimens from the Osteological collection, which, as yet unknown to the public, contains hidden treasures of inestimable value. I am also indebted to Prof. H. G. Seeley for several valuable suggestions.

Besides the three species accurately described by Falconer, Messrs. Baker and Durand ably noticed the remains of several Carnivora in the pages of the Journal of the Asiatic Society of Bengal §; and lately

* Asiatic Researches, vol. xix.

† *Op. cit.* pp. 315, 321, 331. The figures 1–4, pl. xxv., accompanying the description of *F. cristata* in Pal. Mem., are wrongly referred to that species; and the index to the unpublished pl. K (Pal. Mem. vol. i. p. 548) is, by an error, headed *Felis cristata.*

‡ These figures are contained in the unpublished plates K, L, M, N, O, P, Q, now preserved in the Geological Department of the British Museum.

§ *Op. cit.* vol. v. p. 579.

Mr. Lydekker has discovered four new and interesting species of Carnivora*.

The following is a complete list of fossil Carnivora from the Sivālik Hills known at present:—

1. *Amphicyon palæindicus*, Lydekker.
2. *Hyænarctos sivalensis*, Falc. et Cautl.
3. —— *palæindicus*, Lydekker.
4.†*Lutra palæindica*, Falc. et Cautl. et nob.
5.‡*Mellivora* (*Ursitaxus*) *sivalensis*, Falc. et Cautl.
6. *Enhydriodon sivalensis*, Falc. et Cautl.
7. *Ictitherium sivalense*, Lydekker.
8.† *Viverra Bakerii*, nob.
9.§ *Canis curvipalatus*, nob.
10.†—— sp.?
11.†*Hyæna sivalensis*, Falc. et Cautl. et nob.
12.†—— *felina*, nob.
13. *Felis cristata*, Falc. et Caut.
14.†—— sp.?
15.†*Machærodus sivalensis*, Falc. et Cautl. et nob.
16.†—— *palæindicus*, nob.
17. *Pseudælurus sivalensis*, Lydekker.

Until lately the Sivālik fossils used to be quoted by palæontologists as Miocene; but the Geological Survey of India refer the ossiferous Sivālik strata to the Pliocene epoch; and Messrs. Medlicott and Blanford have, in their valuable 'Manual of the Geology of India,' entered into a very elaborate discussion regarding their age. From the stratigraphical evidence, according to them, "there can be no reasonable doubt that the Manchhar beds of Sind, as a whole, correspond with the Sivālik formation of Northern India;" and the Lower Manchhar beds are shown by them to be most probably Upper Miocene||. But the evidence for correlating these beds with the Lower Sivāliks (the Nāhans), which are perfectly unfossiliferous, and the "almost unfossiliferous Upper Manchhar beds to the ossiferous strata of the Sivāliks," is, to say the least, not incontrovertible. Correlation of strata in the absence of fossils would be necessarily uncertain, especially seeing that, as we are informed by Messrs. Blanford and Medlicott, it is "extremely difficult to trace particular zones amongst the confused and contorted mass of the newer Tertiary deposits in the sub-Himalayan ranges and the Punjab." There is no reason why a part of the Lower Manchhars should not correspond to a part of the Sivāliks above the Nāhan group. Our knowledge of the Lower Manchhar fauna is derived from remains which, according to

* Records of the Geological Survey of India, vol. x. pt. 1, p. 32, pt. 2, p. 83; vol. xi. pt. 1, p. 103.

† Described here.

‡ Described by Messrs. Baker and Durand under the generic name of "*Gulo*" (J. A. S. of Bengal, vol. v.).

§ Description of Messrs. Baker and Durand supplemented here.

|| Manual of the Geology of India, p. 581.

Messrs. Blanford and Medlicott, "are extremely fragmentary, and chiefly consist of single teeth and broken portions of bones"*. Fifteen species of Mammalia have been determined from such remains; and of these ten are also met with in the ossiferous Sivāliks. One would therefore feel some hesitation in referring the latter to an age subsequent to that of the Lower Manchhars.

The palæontological evidence adduced by the learned geologists is, according to their own admission, far more unsatisfactory. In fact, in order to explain the Miocene facies of the Sivālik fauna, they have had to adopt the theory that some of the European Miocene forms survived in the Sivālik area during Pliocene times. The theory is simple in itself; and no objection can be raised against it. But obviously we should have recourse to such a theory only if the ossiferous Sivāliks were proved by clear stratigraphical evidence to belong to the Pliocene epoch, or if the Sivālik fauna could be shown to have decidedly stronger affinities with the Pliocene than with the Miocene faunas of other localities. It is greatly to be regretted that the exact horizons from which the fossils have been collected are not known; and there can be no doubt that a few of these (though their number must be very limited) are more recent than the rest. But it is certain that by far the great majority of the animals composing the Sivālik fauna lived at an epoch intermediate between the Middle Miocene and the Middle Pliocene; and the question is whether the fauna should be quoted as Upper Miocene or Lower Pliocene. I shall here only attempt to answer this question on the palæontological evidence afforded by the Carnivora, the subjects of this description; but I may say that if the Sivālik fauna were discussed as a whole, the answer would not be different.

There are 12 genera of Carnivora known from the Sivāliks. Of these, six (*i. e.* half), viz. *Machærodus*, *Pseudælurus*, *Ictitherium*, *Amphicyon*, *Hyænarctos*, and *Enhydriodon*, are extinct. Of the 11 genera of Carnivora† known from the Miocene of Sansan and Simorre, 6 (*i. e.* a little more than half) are extinct, viz. *Machærodus*, *Pseudælurus*, *Amphicyon*, *Hyænarctos* (*Hemicyon*), *Ictitherium* (*Thallassictis*), and *Pseudocyon*. The first five of these genera are common to the Sivāliks; *Machærodus* ranges from Miocene to Pleistocene; but *Pseudælurus*, *Amphicyon*, and *Hyænarctos* are characteristically Miocene genera, though the first and the third have been met with in deposits of Pliocene age, the former in America, and the latter in Europe. *Amphicyon*, however, is not yet known to have survived the Miocene epoch. *Enhydriodon* has been hitherto confined to the Sivāliks. Now if we examine the Lower Pliocene fauna of Montpellier‡, or the Upper Pliocene fauna of Mount Perrier§, we find only one extinct Carnivore, and that the ubiquitous *Machærodus*. The fauna begins to assume an altogether recent aspect. The fossils found at Pikermi present, as a whole, a close parallel to those from the Sivālik Hills—so much so that Messrs. Medlicott and

* *Op. cit.* p. 471.
† Pictet, 'Traité de Paléontologie,' tom. iv. p. 677.
‡ Pictet, *op. cit.* p. 681. § Pictet, *op. cit.* p. 683.

Blanford have made the age of the latter to hinge on that of the former. After quoting M. Gaudry's authority to prove that the Pikermi fauna is Pliocene and not Miocene, they conclude by saying that "there can be, therefore, no reasonable doubt that the Pikermi fossils, like the Sivālik, are of Pliocene age, and that the quotation of them as Miocene is an error"*. But if it is an error to quote the Pikermi fauna as Miocene, M. Gaudry himself, on whose authority this conclusion is based, is guilty of it; for in his latest work† he constantly cites the Pikermi fossils as Upper Miocene. Considering, therefore, the strong affinities of the Sivālik fauna, as a whole, to the known Miocene fauna, and having regard to its close relationship with the Pikermi fauna, it would, I venture to suggest, be advisable, for historical purposes, to place it on the same horizon as the latter, and regard them as Upper Miocene. In the Sivālik fauna, however, there is most probably an admixture of some Pliocene forms.

It will be seen from the list given above that there are 17 species of Carnivora known to occur as fossil in the ossiferous Sivāliks; but there are indications of some more. In the collection of the British Museum there are several mutilated skulls belonging, most probably, to small forms of Carnivora, but the affinities of which, in the absence of dentition, I have been unable to determine exactly. We may therefore safely add 3 more species, making the total number 20. In the Sivālik area, at the present day, there are altogether 17 or 18 species of Carnivora ‡, showing a decrease of 3. The Carnivore fauna of India consists of about 40 species §, that is to say, double the number known from the Sivāliks. This is owing to the increase in the *smaller* forms, the number of the larger forms having decreased. The numerical strength of the existing Carnivore fauna of India presents a striking contrast to the extreme poverty of the Ungulate fauna (including the Proboscidians), which does not consist of more than 27 species ‖. No less than 60 species of Ungulates (including Proboscidians) are known from the Sivālik beds—that is to say, more than double the number now inhabiting the whole of India. The proportion of the fossil to the living Ungulates in the Sivālik area itself, as pointed out by Messrs. Medlicott and Blanford, is as 5 to 2. We therefore come to the conclusion that if the Carnivore fauna has been impoverished, the impoverishment has been considerably less than that of the Ungulate fauna.

MACHÆRODUS SIVALENSIS, Falc. et Cautl. et nob. (Pl. VI. fig. 5.)

Two imperfect crania, six fragments of lower jaws, and two of upper jaws, in the collection of the British Museum, are all labelled *Drepanodon* (*Machærodus*) *sivalensis*. Of the six specimens of lower

* *Op. cit.* p. 584.

† 'Les enchaînements du Monde Animal,' Paris, 1878, pp. 48, 264, 265, 271, 273, &c.

‡ Medlicott and Blanford, *op. cit.* p. 589.

§ Jerdon's 'Mammals of India,' pp. 68–154.

‖ Jerdon, *op. cit.* p. 228.

jaw, two* evidently belong to *Felis*, probably to the *Felis cristata* of Falconer; two others have been added to the collection since Dr. Falconer's death, and are not mentioned in the 'Palæontological Memoirs.' These are of much larger dimensions than, and otherwise differ from, the two remaining fragments of lower jaw. Of the crania, the size agrees with that of the former, which I have separated as belonging to a distinct species.

Of the four specimens for which I have retained the specific name of "*sivalensis*"†, two have been briefly described by Prof. Owen‡. One is a fragment of upper jaw with evidently the deciduous dentition, and the other is a portion of the lower jaw. The first is thus noticed by the learned palæontologist:—

"The molar series in the Sivālik *Machœrodus* includes, in an extent of 1½ inch, three teeth; the first, which is simple, single-fanged, and very small, is indicated by the socket; the second, measuring 8 lines in the antero-posterior diameter, is the carnassial or sectorial tooth; its crown is more compressed, its trenchant margins sharper, and the inner tubercle less developed than in the normal species of *Felis*. The socket of the third or tubercular molar is behind, or in a line with the sectorial tooth, as in the milk-teeth of the Lion. What remains of the canine indicates its great length; the breadth of its base is 5 lines; it is much compressed: the inner surface is flat, and both edges are finely but distinctly serrated."

On a careful examination of the specimen§ in question, I am obliged to differ from so high an authority as Prof. Owen in some points contained in the description just quoted. The canine and sectorial are *in situ*; and there is the alveolus for the back molar, which, as in the deciduous dentition of *Felis*, is very large. But I find no indication whatever of the presence of a molar between the sectorial and canine‖; and I submit that, reasoning *à priori*, we should not expect to find that molar. The dentition in the specimen is obviously the deciduous dentition, as stated by Prof. Owen himself¶. In the adult *Machœrodus*, with the single exception of

* B.M. no. 16537 and no. 16573; Pal. Mem. vol. i. p. 551; Fauna Antiq. Siv. unpublished plate N, figs. 6, 6*a*, 7, 7*a*. I find that Mr. Davies, too, referred these figures to the genus *Felis*.

† M. Pomel notices the Sivālik *Machærodus* as *Meganthereon Falconeri* (Cat. des Vert. Foss. &c. p. 56). M. Gaudry, following Pomel, mentions it as *Machærodus Falconeri* (An. foss. de l'Attique, p. 113).

‡ 'History of Brit. Foss. Mamm.' pp. 178, 179.

§ The specimen has been figured in one of the unpublished plates (pl. N) of the 'Fauna Antiqua Sivalensis.' But the artist, Mr. Ford, who was generally very careful, has by an error represented a tooth in front of the sectorial (fig. 3*a*). The specimen has been refigured in Pal. Mem. (pl. xxv.). It is numbered in the B.M. 16350.

‖ Dr. Falconer, in a note on *Felis spelæa* (Pal. Mem. vol. ii. p. 456), expresses the same opinion. He says:—"In the Sewalik specimen [of *Machærodus*] there is an interval between the carnassier and canine of 0·3 inch, part of which has been *artificially rubbed down*; but there is not the *least indication of a fang-pit or fang* [Owen says there is, and that it is single-fanged and simple!]." (The italics are mine.)

¶ *Op. cit.* p. 178.

Leidy's somewhat aberrant species (*M. primævus*) *, there are altogether three molars, the anterior false molar of *Felis* (pm. 2) being absent. Now this tooth replaces the first milk-molar, that is to say, the molar between the deciduous sectorial and the canine †. Hence, as the anterior premolar of *Felis* is absent in the adult dentition of *Machærodus*, we should expect the corresponding molar of the milk-dentition also to be absent in the latter. The anterior false molar of the adult *Machærodus* is the homologue of the second of the molar series in *Felis*, and, as in this genus, replaces the deciduous sectorial, the permanent sectorial taking the place of the large back molar of the milk-dentition. Thus the deciduous dentition of the upper jaw on each side in *Machærodus* would be

d. i. 3, d. c. 1, d. m. 2=6,

instead of

d. i. 3, d. c. 1, d. m. 3 (*Felis*)=7.

There are two other points in Prof. Owen's description which call for a word or two by way of comment. He says that the "inner tubercle of the sectorial is less developed than in the normal species of *Felis*." But it is not developed at all. Both edges of the canine are asserted by the eminent naturalist to be "finely, but distinctly serrated." The serration of the posterior edge is distinct, but the anterior edge is damaged; and we cannot determine whether it was serrated or not.

The other fragment of upper jaw (B.M. no. 39730) evidently belongs to an adult individual, and exhibits three molars *in situ*. The canine has been removed, and the hinder part only of its alveolus is visible. It is separated by a short diastema (0·35 inch) from the anterior premolar, which is the homologue of the second of the molar series in *Felis*. It is two-fanged, the fangs being divergent. The crown has been damaged; but the base shows the tooth to have been smaller than the corresponding tooth of *M. neogæus*, as well as of *M. meganthereon*. The sectorial is intermediate in size between these two species; in antero-posterior length it is a little less than double the deciduous sectorial, and is much more stout and less trenchant than the latter. There is no internal tubercle, but a slight thickening of the cingulum is visible in its place; and a prominent flattened ridge (absent in the milk-sectorial) ascends from the thickened portion to the summit of the second of the three lobes into which the blade is as usual divided. In the anterior of these lobes a notch maps off a small lobe in front and a considerably larger one behind. The middle lobe has an elevated, triangular, pointed crown; the posterior lobe has a low, horizontal, sinuous edge.

Of the two fragments of lower jaw one has been briefly described by the learned comparative anatomist I have quoted above ‡. It

* 'Anc. Fauna of Nebraska,' p. 96. † Owen's 'Odontography,' p. 489.

‡ Owen, 'Brit. Foss. Mamm.' p. 179, figs. 4, 4*a*; unpublished plate N, Fauna Antiq. Siv.; fig. 6, pl. xxv. Pal. Mem. vol. i.

shows well the downward and forward extension of the mandibular symphysis, which is more elevated than in *M. meganthereon.* The canine is absent; but, from its inferred position, the diastema between it and the first false molar may be concluded to have been shorter than either in *M. neogæus* or *M. meganthereon*; and the height of the ramus in front of the molar series is proportionately greater than in these two species. These peculiarities are better exhibited by the specimens to be described under the next species. The crown of the first premolar is broken off, but it is entire in the other fragment of lower jaw*. The anterior accessory cusp, which is well developed in *M. meganthereon*, as well as in *M. neogæus*, is entirely absent; and the posterior is not so well marked as in these two. The antero-posterior extent of the crown is less than in *M. meganthereon* †. The next premolar (pm. 4) slightly overlaps the carnassial, and is composed of a low anterior cusp, a deltoid middle lobe, and a bilobed posterior cusp, the summits of all these pointing backwards, as in the Brazilian and French species. The antero-posterior length of the carnassial, like that of the preceding molar, is intermediate between that of the corresponding tooth in these two species.

MACHÆRODUS PALÆINDICUS, nob. (Pl. VI. figs. 1–4.)

The specimens just described indicate a species of *Machærodus* as large as the Jaguar‡; but the two specimens of lower jaw§ which have been added to the collection since Dr. Falconer's death, as well as the two crania mentioned above, must have belonged to much larger individuals, nearly equalling in size the Royal Tiger of Bengal.

One of the fragments of lower jaw exhibits the symphysial extension downwards very well. In the other known species of *Machærodus* the extension takes place below the canine; but in *M. palæindicus* the downward prolongation of the outer border of the ramus takes place further back, below the second false molar (pm. 4). The fossa for the reception of the upper canine is much better defined than in any other species. In the Brazilian, as well as the French form, the border of each ramus curves upwards in front of the anterior premolar, and then downwards to meet the symphysial extension. But in both the Sivālik forms there is no such curvature; consequently the height of the diastema (especially in *M. palæindicus*) between the canine and the first false molar is considerably greater. This, coupled with the relative shortness of the diastema, gives a very formidable look to the lower jaw of *M. palæindicus.* As noticed by De Blainville in *M. meganthereon*‖, the mental foramen is situated further down than in the Lion or the Tiger. I have observed, in addition, that there is, as a rule,

* B.M. no. 16554; figs. 8, 8 *a*, unpublished plate N (F. A. Siv.).

† The first premolar (pm. 3) is of very variable size in *M. neogæus*; and in one of the specimens in the British-Museum collection it is entirely absent.

‡ Owen, *op. cit.* p. 178.

§ B. M. nos. 48436 and 48437.

‖ 'Ostéographie,' genus *Felis*, p. 130.

only one mental foramen; and this, or, if there are two (as in a specimen of the lower jaw of *M. neogæus* in the British Museum collection), the posterior of these is situated in front of a vertical line drawn from the front base of the anterior premolar; whereas in the Lion or the Tiger, in which there is always more than one mental foramen, the hindermost is situated behind that line. The canine and the first false molar are indicated by their alveoli; in antero-posterior length the latter is larger than the corresponding tooth of *M. meganthereon*. The next molar (pm. 4) and the carnassial are *in situ*, but they are both damaged; they are about the same size as the corresponding teeth in the Brazilian *Machærodus*.

The remaining specimens consist of the posterior portion of a skull* and a nearly entire, but mutilated, cranium†, which has been a good deal crushed.

They present the following peculiarities:—

1. The facial portion is considerably less in length than the cranial. This is a peculiarity common to the other species of *Machærodus*, and also to the *Felis cristata* of Falconer, which, as noticed by that learned comparative anatomist, is the only large feline animal that presents this Hyænoid characteristic.

2. The sagittal crest, which is very prominent, slopes gradually in front up to its point of bifurcation. This characteristic is also shared by the other two species of *Machærodus*, and, it is interesting to observe, by *Felis cristata* and *F. grandicristata* (?) alone of all the larger forms of *Felis*.

3. The zygomatic process of the squamosal is prolonged vertically downwards so as to form a strong and stout pedicel, separated by a narrow valley from the mastoid.

4. The mastoid portion of the periotic is of much greater extent, and is prolonged further downwards than in either the Lion or the Tiger.

5. The occipital crest is very high.

The following measurements of *M. meganthereon*, and also of the bones of the skull and the upper-jaw teeth of *M. neogæus*, have been taken from the beautiful figures in De Blainville's Atlas‡; the measurements of the lower jaw of the last species have been taken from two specimens in the collection of the British Museum:—

* B. M. no. 39728; figs. 1, 1*a*, 1*b*, 1*c*, unpublished pl. N (F. A. Siv.).

† B. M. no. 39729; figs. 2, 2*a*, &c., unpublished pl. N (F. A. Siv.).

‡ Ostéographie, Atlas, genus *Felis*, pls. xvii. and xx.

	M. sivalensis. (adult.)	*M. palæindicus.*	*M. megantereon.*	*M. neogæus.*
	in.	in.	in.	in.
UPPER JAW.				
Antero-posterior length of premolar 3 (first of the molar series)	0·45	...	0·575	0·7
Antero-posterior length of the sectorial	1·3	...	1·1	1·67
Antero-posterior length of the tubercular	0·15			
Transverse length of the tubercular	0·275			
LOWER JAW.				
Antero-posterior length of premolar 3 (first of the molar series)	0·35	0·5	0·4	
Ditto, ditto of pm. 4	0·75	0·9	0·65	0·925
Ditto, ditto of carnassial.........	0·95	1·1	0·75	1·125
Length from the postorbital apophyses to the border of the incisives	...	4·425 (?)	4·25	4·75
Length from the postorbital apophyses to the occipital crest	...	6	4·75	6·25
Maximum height of the diastema (outer border) between the canine and pm. 3	1·75	2·3	1·175	1·575
Length of the diastema............	...	1·275	...	1·95
Extreme height from the base of foramen magnum to occipital crest................................	...	4·1		

[With regard to the relations of the Sivālik species to *M. cultridens*, *M. latidens*, and *M. palmidens*, nothing can be said at present, as, with the exception of an imperfect specimen of the milk-canine, neither this tooth nor the incisors of the Sivālik species have yet been discovered. *M. palmidens*, however, could be distinguished by the size and form of the two lower premolars.]

FELIS, sp.?

The specimen consists of a cranium* deficient in the facial portion in front of the orbits. The zygomatic arches, brain-case, and its base are beautifully preserved. The specimen is not mentioned in the 'Palæontological Memoirs,' but it is entered as *Felis cristata* (?) in the catalogue of the British Museum, and, as I am informed by Mr. Davies, comes from the Sivālik Hills. The skull belonged to an animal considerably larger than *Felis cristata*, and of about the same size as the larger varieties of the Royal Tiger. The sagittal crest (slightly damaged posteriorly) is much thicker

* B. M. no. 49175.

and more prominent than in *Felis cristata*, and stands vertically on the roof of the cranium. Its height anteriorly is six times greater than the corresponding height in the Tiger. The ridges which originate from behind the postorbital processes of the frontal are stronger and run obliquely to a greater distance than in any other large forms of *Felis*; and these, instead of perfectly blending to form the sagittal crest, run parallel nearly as far as the occiput, forming a narrow and shallow groove along the median line of that crest. The triangular valley included between the frontal ridges in front of the parietal crest, as well as the frontal fossa between the postorbital apophyses, slopes anteriorly, as in *Felis cristata,* and not posteriorly, as in other large Felidæ. The depth of the mesopterygoid fossa, as well as the length of the basicranial axis, is very nearly the same as in the larger individuals of Tiger; but the breadth of the cranium at the zygomatic arches is proportionately much smaller than in the latter.

	inches.
Length of basicranial axis to the anterior extremity of the mesopterygoid fossa	5·075
Depth of the mesopterygoid fossa	1·025
Extreme breadth at zygomatic arches......	8·125
Greatest breadth between outer surfaces of the occipital condyles	2·775

Further evidence is necessary before the species can be clearly separated from *F. cristata.* If it should prove a distinct species, as I am inclined to think it will, I propose to call it *F. grandicristata.*

Hyæna sivalensis, Falc. et Caut.? et nob.*

The specimens consist of a tolerably perfect cranium and portions of palate and of upper and lower jaws †. These indicate an animal of about the same size as the living Indian Hyæna (*H. striata*). One of the specimens shows the incisors and the canine *in situ,* the former being much better developed than the corresponding teeth in the living Indian Hyæna. The crown of the second premolar, which is proportionately larger than in any of the living species, is formed by a stout cone; the anterior accessory cusp, so well marked in the living Indian Hyæna, is entirely absent; but the posterior accessory

* Dr. Murchison heads the indices to the plates L & M as *Hyæna sivalensis* (Falc. & Cautl.) (Pal. Mem. vol. i. p. 548); but in the same page he says:—"Unfortunately . . . . . no account of it is to be found among Dr. Falconer's notes. This species is, no doubt, that designated *Hyæna sivalensis* by Messrs. Baker and Durand in the brief description given by them in the Journal of the Asiatic Society for October 1835, vol. iv. p. 569." If it were so, the specific designation would be due to Baker and Durand, and not to Falconer and Cautley. But I have not met with it anywhere except in the Palæontological Memoirs, and on the unpublished plates L and M of the F. A. Siv., where the name occurs in pencil writing, which Mr. Davies identified as Dr. Murchison's.

† B. M. nos. 37133, 37137, 37138, 37139, 16583, 16578, 39731, 37141. Figs. 2, 2*a*, 2*b*, 2*c*, unpub. pl. K; figs. 2, 2*a*, 2*b*, 6, 6*a*, 7, 7*a*, 8, 8*a*, unpub. pl. L; figs. 5, 5*a*, 7, 8, 8*a*, unpub. pl. M. The cranium has been refigured in Pal. Mem. vol. i. figs. 1, 2, 3, 4, pl. 25, under the title of *Felis cristata.*

cusp is present. The cingulum is very pronounced, except posteriorly, and swells antero-internally into a talon-like prominence, from which a well-defined ridge ascends up the crown. The third premolar differs from the preceding in its greater size and in having the posterior accessory cusp proportionately less developed. The fourth premolar or sectorial consists, as usual, of a blade divided into three lobes and of a stout trihedral internal tubercle, separated from the outer lobes by a deep valley; the elongation of the posterior lobe of the blade approximates the fossil to *H. crocuta*. But the tubercular is still more highly developed proportionately than in the living Indian Hyæna, thus differing remarkably from the Cape Hyæna. This tooth is triangular and three-fanged. In the lower jaw, the first and second false molars (pm. 2 and pm. 3) are entirely devoid of the anterior accessory cusps so well developed in *H. striata*. The third premolar (pm. 4) consists of a principal cone, a rudimentary anterior accessory cusp, and a tolerably well-developed posterior one. Two prominent longitudinal ridges, one anterior and the other posterior, ascend up the principal cone and divide it into two faces, of which the outer is much more convex than the inner. The dimensions of the tubercular part of the first molar or carnassial are intermediate between those of the corresponding part in the striped and the Cape Hyænas. The accessory cusp at the inner and posterior part of the base of that tooth is either entirely absent or, if present, quite rudimentary, thus differing remarkably from the living Hyæna of India, and approximating to *Hyæna crocuta*.

The large tubercular molar of the upper jaw in the fossil under examination differentiates it from *H. spelæa* and the allied species, or, rather, varieties, *H. intermedia* and *H. Perrieri* *. It is distinguished from *H. prisca* and *H. arvernensis* by the absence of the anterior accessory cusps in the premolars †. The antero-posterior length of the upper tubercular in *H. hipparionum* ‡ is proportionately much greater. *H. eximia* § is separated, by the presence of premolar 1 in the lower jaw, from all other known species of Hyæna.

In its general outline the skull resembles that of *H. striata*. As in the latter, the brain-case is swollen behind and not laterally compressed as in *H. crocuta* or its allied fossil *H. spelæa*. The sagittal crest is very well marked. The lambdoidal crest is not so much reflected back at its apex as in *H. spelæa*. The postglenoidal processes are very stout and strong. The postorbital processes of the frontal are very well developed, and are proportionately longer than in any other known species.

It will be seen from what has been said that while in certain characters, as in the form of the skull, the dimensions of the upper tubercular, &c., *H. sivalensis* comes near to the most primitive of the three living species of Hyæna, in certain other characters, and

* W. Boyd Dawkins, 'Nat. Hist. Rev.' 1865.
† Blainville, 'Atl. d'Ost.' gen. *Hyæna*, pl. viii.
‡ Gervais, 'Zool. et Pal. Fr.' p. 242, pl. xii.
§ Gaudry, 'Anim. foss. et Géol. de l'Attique,' p. 82, pls. xii., xiii., xiv.

notably in the absence or extremely rudimentary character of the postero-internal basal denticule in the lower carnassial, as well as in the entire absence of the anterior accessory cusps in the upper and the first two lower premolars, it approximates to the most differentiated form, now represented by the Cape Hyæna. No other species of Hyæna is known in which there is such a remarkable combination of characters shared by such divergent forms.

	inches.
Length from occipital condyle to the front of the base of the canine	7·555
Height of occipital crest from base of foramen magnum	2·175
Upper jaw—	
Antero-posterior length of alveolus of premolar 1	0·175
Minimum ant.-post. length of premolar 2	0·65
Maximum ant.-post. length of premolar 2	0·775
Minimum ant.-post. length of premolar 3	0·675
Maximum ant.-post. length of premolar 3	0·875
Minimum ant.-post. length of sectorial	1·175
Maximum ant.-post. length of sectorial	1·4
Transverse length of tubercular	0·55
Height of the crown of incisor 1	0·25
Height of the crown of incisor 2	0·3
Height of the crown of canine	0·875
Lower jaw—	
Antero-posterior length of premolar 2	0·575
Antero-posterior length of premolar 3	0·75
Antero-posterior length of premolar 4	0·8
Minimum ant.-post. length of carnassial	1·05
Maximum ant.-post. length of carnassial	1·1

HYÆNA FELINA, nob. (Pl. VI. fig. 6.)

The history of the specimen * on which this species is founded is thus given in the 'Palæontological Memoirs' † in the index to the unpublished plate K (headed *Felis cristata* by an error), in explanation of the figures 1, 1*a*, 1*b*, 1*c*:—"Four different views of an imperfect cranium from Mr. W. Ewer's collection. The left maxillary bone with the teeth is absent; but the portion was found after the drawing was made, and has been added to the specimen in the British Museum."

Dr. Falconer entered the left maxillary bone alluded to here as belonging to *Hyæna* in the British-Museum Catalogue. The skull as it now stands is deficient only in the zygomatic arches, and evidently belongs to an aged individual. The facial portion has suffered a crush anteriorly, and is slightly distorted in consequence. The incisors have been removed. The crown of the canine has been broken off, but its base shows it to have been proportionately stronger than the corresponding tooth of Hyæna; this, however, may be an individual variation. There is *no indication whatever* of the

* B. M. no. 15902. † *Op. cit.* vol. i. p. 548.

presence of premolar 1, which is so constant in all known species of *Hyæna*, living or fossil; and the canine is separated by a short diastema from premolar 2 (first of the molar series in the fossil). This tooth is two-fanged, and resembles the corresponding tooth of *Hyæna* in its dimensions, as may be judged by its base, the crown being broken off. The second false molar too (pm. 3) is in form and size hyænoid. The sectorial is proportionately larger than in the living Indian Hyæna, and is provided with a very strong and stout internal tubercle. The alveolus of the tubercular molar, preserved on the right side, is situated as in the Felidæ, and shows that tooth to have been transverse and *exceedingly small*, thus differing from *H. striata* and *H. sivalensis*. The sagittal crest is very prominent and quite Hyæna-like, gently sloping on the sides; but the occipital crest is proportionately higher than in any other species of *Hyæna*. The specific name given to the fossil is based on the approach it makes to feline organization, especially in the entire absence of premolar 1 from the upper jaw.

In the following measurements the skull of the living Indian Hyæna* selected for comparison is a little smaller than the fossil:—

	Hyæna felina. inches.	Living Indian Hyæna. inches.
Length from the postorbital apophyses to the border of the incisors	5·0	4·175
Length from the postorbital apophyses to the summit of the occipital crest	5·41	5·2
Height of the supraoccipital from the top of foramen magnum	1·875	1·25
Length from the posterior extremity of the basicranial axis to the hinder end of the palate	3·32	3·425
Length from this point to the hinder border of the alveolus of incisor 1	4·375	4·15
Length from the anterior end of the base of the canine to the posterior end of the sectorial	3·85	3·35
Length occupied by the molars	2·82	2·375
Upper jaw—		
Antero-posterior length of canine at its base	0·75	0·575
„ „ premolar 2	0·575	0·525
„ „ „ 3	0·775	0·775
„ „ sectorial	1·35	1·07

VIVERRA BAKERII, nob.

The specimens consist of a mutilated cranium with the third premolar (pm. 3), the sectorial, and the two tuberculate molars of both sides *in situ*, and a portion of the upper jaw containing the sectorial and the first molar. On the authority of the 'Palæon-

* B. M. no. 136, *c*. It is from the Northern Circars.

tological Memoirs' *, these have been labelled "*Canis*," but have a note of interrogation added.

The skull indicates an animal of nearly the same size as the Civet (*V. civetta*). The third premolar, which is proportionately larger than the corresponding tooth in the latter, consists of a stout triangular crown, and presents no division into accessory lobes anteriorly or posteriorly. The cingulum is well pronounced, and sends up a ridge anteriorly, which, meeting with its fellow from behind, divides the crown into two parts, of which the external is much more convex than the internal. The sectorial is like the corresponding tooth in the Civet, but proportionately larger. The anterior of the two lobes into which its blade is divided is thick and conical, with a small accessory lobule in front, and is mapped off by a notch from the posterior lobe. The internal tubercle is stout and strong, and separated by a deep valley from the outer lobes, as in the Civet. The first tubercular is triangular and tricuspid, and is a little larger than the corresponding tooth in that species. The two subequal outer cusps are ground down into flattened crescent-shaped disks; and the inner cusp is separated from them by a deep pit. The second tubercular is proportionately longer laterally and narrower antero-posteriorly than the corresponding tooth in the Civet.

There are only three other fossil species of *Viverra* which have been made out with any thing like certainty, viz. *V. antiqua* and *V. exilis* of De Blainville and *V. sansaniensis* of Lartet. The last two are known by their lower jaws only, so that I am not in a position to compare them with the present fossil. It is readily distinguished from *V. antiqua* by the proportionately smaller size of the teeth, especially of the hindermost tubercular, in the latter species †.

In the following measurements the skull of the Civet selected for comparison is a little larger than the fossil:—

	Viverra Bakerii. inches.	*Viverra civetta.* inches.
Length from the posterior extremity of the basicranial axis to the anterior extremity of the palate	4·55 (?)	5·1
Length from the anterior extremity of pm. 3 to the posterior extremity of m. 2	1·4	1·25
Upper jaw—		
Antero-posterior length of premolar 3	0·4	0·32
Maximum transverse diameter of ditto	0·2	0·2
Antero-posterior diameter of the sectorial at the base (outer border)	0·6	0·5
Height of internal tubercle of sectorial	0·2	0·2
Transverse diameter at base of m. 1	0·5	0·45
,, ,, m. 2	0·4	0·3
Antero-posterior diameter of ditto	0·2	0·25

* Vol. i. p. 153. Mr. Davies had originally labelled the skull "*Viverra*." It is figured in an unpublished plate (figs. 1, 1*a*, 1*b*, and 3, pl. Q). B. M. nos. 40183 and 40180.

† Gervais, 'Zool. et Pal. Fr.' p. 223, pl. 28; De Blainv. Atl. d'Ost. (gen *Viverra*), pl. xiii.

LUTRA PALÆINDICA, Falc. et Cautl. et nob.

A specimen of cranium (B. M. no. 37151), deficient in the zygomatic arches, and another of the lower jaw (B. M. no. 37152) are so named in the index to the unpublished plate L of the 'Fauna Antiqua Sivalensis' *. The cranium shows the alveoli of the three incisors and the canine (on each side), and of the three anterior false molars (of the left side). The sectorial and the tubercular of this side, as well as the lower carnassial, are *in situ.*

In the number, form, and disposition of the teeth the fossil agrees very closely with the living Indian Otter †; but the skull of the fossil is smaller, and the teeth proportionately larger. The brain-case is broader and higher in the fossil than in its living representative. But the most characteristic feature in the fossil skull is the form of the forehead. In the common as well as in the Indian Otter the frontal narrows from behind the postorbital process, in the shape of a triangle, up to its junction with the brain-case proper; but in the fossil the part between the postorbital processes of the frontal and the cranial cavity is wider and is of uniform breadth throughout, so as to be quadrangular instead of triangular. In this respect the fossil resembles a peculiar form of Otter described by Gray as *Lutronectis* ‡; but the orbit of the latter is scarcely defined behind.

Lutra Bravardi (with which Gervais § and Pictet ‖ incorporate *L. elevaris* and *L. clermontensis* ¶) and *L. dubia* **, especially the latter, are considerably larger than the Sivālik fossil. The tubercular is squarer in *L. Bravardi* than in either the living or the fossil Indian Otter ††. *L. affinis* is very like the common European Otter (*L. vulgaris*), and thus readily distinguished from the fossil under examination ‡‡.

	Lutra palæindica.	Living Indian Otter.
	inch.	inch.
Length from the posterior extremity of the basicranial axis to the anterior of incisor 1, taken as modulus	1·0	1·0
Height of occiput from the top of foramen magnum	0·251	0·189
Greatest breadth of the surface of brain-case opposite mastoid processes	0·587	0·466
Minimum breadth of frontal behind its postorbital processes	0·216	0·141
Breadth of cranium at these processes	0·251	0·209
Greatest height of lower jaw below carnassial	0·139	0·11

* Pal. Mem. vol. i. p. 552. The specimens have been refigured in pl. xxvii. (figs. 5 & 7) of Pal. Mem.

† The skull of the Indian Otter I have had for comparison comes from Madras, B. M. no. 1668 *a.*

‡ 'Catalogue of the Carnivora,' p. 107. It may be noted that in the absence of the contraction of the frontal behind the orbits, as well as the proportionately greater capacity of the brain-case, the fossil approaches the Polecats.

§ Zool. et Pal. Fr. p. 243.

‖ Traité de Pal. tom. i. p. 210.

¶ Blainv. Ostéographie (gen. *Mustela*), p. 52, pl. xiv.

** Blainv. *op. cit.* pl. xiv.

†† Gervais, *op. cit.* pl. xxvii. fig. 6.

‡‡ Gervais, *op. cit.* p. 244.

	Lutra palæindica.	Living Indian Otter.
Upper jaw—	inch.	inch.
Length occupied by the incisors on each side	0·077	0·061
" " molars and canines	0·385	0·343
Antero-posterior length of canine........	0·084	0·061
" " sectorial (outer border)	0·127	0·111
Maximum transverse diameter of tubercular	0·127	0·111
Antero-posterior length of tubercular (outer border)	0·09	0·084
Lower jaw—		
Length occupied by the molar series	0·39	0·343
Antero-posterior length of carnassial	0·146	0·14

[The length taken as modulus in the above measurements is 3·575 inches in the fossil, and 4·075 inches in the living Indian Otter selected for comparison. The absolute measurements can be deduced from this.]

CANIS CURVIPALATUS, nob.

The specimen consists of a cranium deficient only in the zygomatic arches and in the anterior portion of the palate. The lower jaw of the left side shows the three hinder premolars and the first two molars *in situ*, and the alveoli of the first premolar and the last molar. The lower jaw of the right side is broken off posteriorly, but is more complete in front than its fellow of the left side and shows the base of the canine. The cranium has suffered from a crush, and has, in consequence, been somewhat flattened anteriorly; but no distortion, at least to any considerable extent, has taken place. The cranium was briefly described and figured by Messrs. Baker and Durand in the Journal of the Royal Asiatic Society of Bengal for 1836*. By comparing it with one of a living Indian Fox (with which the fossil is most closely allied), those able palæontologists found that the fossil, while agreeing generally with the latter, differed from it in the greater breadth of the brain-case, the height and thickness of the lambdoidal crest at the summit of the supraoccipital, the greater concavity and size of the postorbital processes of the frontal, and the closer approximation of the false molars in the upper jaw; but they did not notice the following important peculiarities of the fossil, nor did they give it any specific name:—

(1) In all Canidæ, and more or less in all other Carnivora, the basifacial axis is parallel to the basicranial axis; but in the fossil now under examination the palate makes an angle, though a very open one, with the base of the cranium, somewhat as in the Rabbit. The specific name is derived from this the most characteristic feature of the fossil.

* This description has been quoted in the Pal. Mem. vol. i. p. 341.

(2) The rami of the lower jaw are not so much compressed as in the living species of the Canidæ.

(3) Each ramus, instead of being straight, forms an arc of a circle between the angle and the mandibular symphysis.

(4) As in the upper jaw, the premolars in the lower jaw also are closer together than in the Fox.

(5) The internal tubercle of the sectorial is stouter than in the Fox.

(6) The upper tuberculars, especially the hindermost one, are proportionately larger.

Messrs. Baker and Durand noticed a peculiarity about the frontal ridges, that these, starting from the rear of the postorbital apophyses, "converge towards the occiput in a curvilinear direction, until the distance between them is reduced to about half an inch, after which they run nearly parallel for some distance, and then converge again, till they unite near the occiput and become blended with the parietal crest." I find this peculiarity, which is absent in the European Fox, well marked in both the specimens of the Bengal Fox* (*Canis bengalensis*) I have had for comparison, as well as in the Fennecs †.

CANIS, sp.? (Pl. VI. figs. 7–9.)

One of the two posterior parts of lower jaw ‡ on which this species is founded was labelled by Dr. Falconer as "*Enhydriodon*;" and in a memorandum, published in the 'Palæontological Memoirs' §, he gives the measurements of the teeth and compares them with those of the Otter. The carnassial and the tubercular following it are *in situ*; but behind the latter there is a distinct alveolus for a small molar, which must have escaped the attention of Dr. Falconer. This tooth is *in situ*, though partially damaged, in the other fragment, which is exactly similar to the one supposed by Dr. Falconer to belong to his *Enhydriodon*. The specimens ‖ indicate an animal of the size of the Wolf; and the form of the teeth is exactly as in that animal. On comparing the two fragments with the lower jaw of the living Indian Wolf ¶ from the osteological collection of the British Museum, the rami are found to be higher and thicker and the teeth proportionately smaller in the fossil. These differences are exhibited by the following measurements:—

	Canis sp.?	Living Indian Wolf.
	inch.	inch.
Ant.-post. length of the carnassial	0·95	1
„ „ molar 2	0·425	0·475
Height of ramus below carnassial	1·1	1·025
Thickness of jaw	0·5	0·4

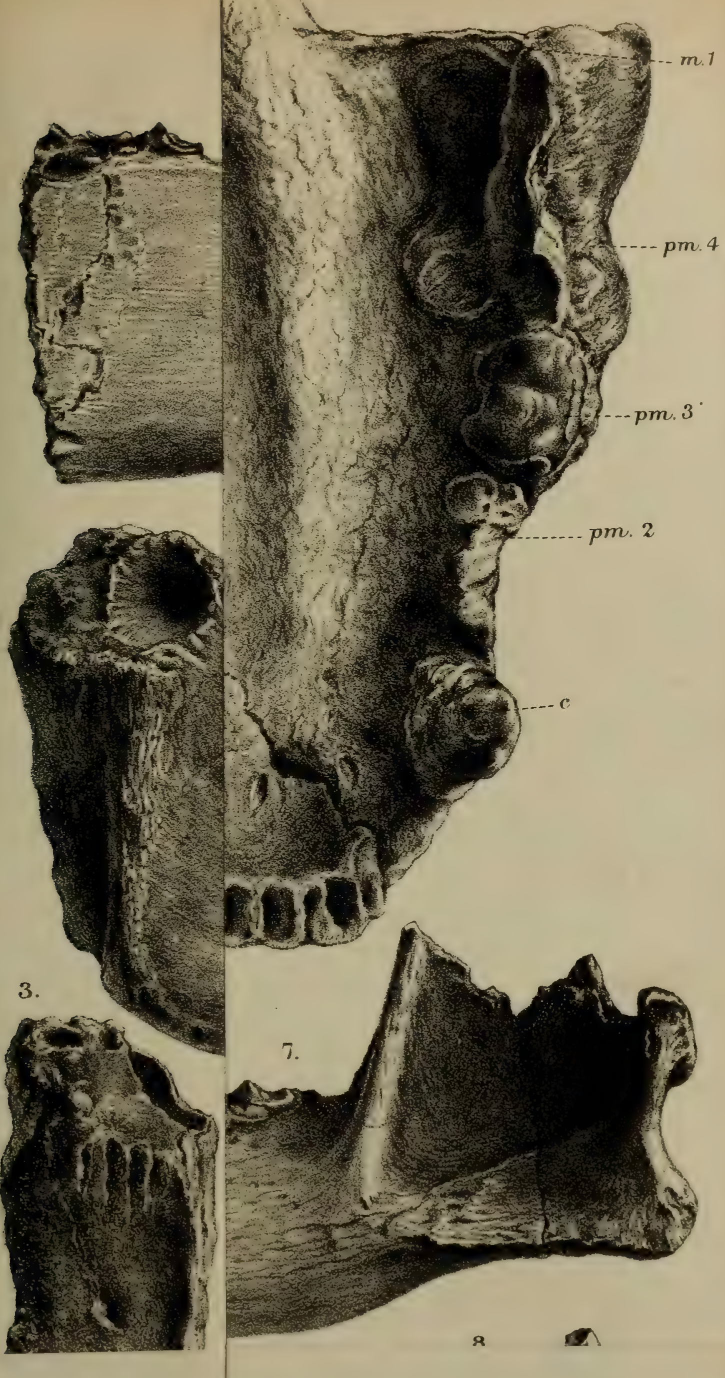
These differences may be only varietal; but it is highly probable that further evidence will establish the distinctness of the present form; in which case I propose to call it *C. Cautleyi*.

* B. M. nos. 174 *h* and 174 *b*.
† B. M. nos. 182 *c* and 815 *a*.
‡ B. M. nos. 40181 and 40182.
§ Vol. i. p. 337.
‖ These have been labelled as "*Canis*" by Mr. Davies.
¶ "*Lupus pallipes*" in Gray's Catalogue. No. 164 *g*.

EXPLANATION OF PLATE VI.

Figs. 1–4. *Machærodus palæindicus*, sp. nov.
1. Inner view of anterior portion of lower jaw.
2. Outer ,, ,, ,,
3. Front ,, ,, ,,
4. Outer ,, posterior ,,

5. Upper deciduous dentition of *Machærodus sivalensis*.
6. *Hyæna felina*, sp. nov.
7–9. *Canis*, sp. Fragments of lower jaw.


m.1
pm.4
pm.3
pm.2
c
3.
7.
8

A S Foord lith.

SIVALIK CARNIVORA

Mintern Bros imp

12. *On the* Oligocene Strata *of the* Hampshire Basin. By Prof. John W. Judd, F.R.S., Sec. G.S. (Read February 4, 1880).

[Plate VII.]

Contents.

I. Introduction.

There are perhaps few portions of the series of British strata which have attracted so large a share of the attention of geologists, both in this country and abroad, as the fluvio-marine formation which constitutes the highest member of the Tertiaries of the Hampshire basin. When we remember the numerous memoirs which, since the commencement of the present century, have been devoted to a description of these strata and of their fossils, it might well be supposed that little can remain to be done, either in working out the order of succession of the beds, or in determining their relations to the deposits of other areas. That such is not the case, however, I shall have occasion to show in the memoir which I now submit to this Society; and it may be well that, at the outset of this inquiry, I should briefly indicate the difficulties which beset the study of this particular formation, and the causes which have led to the serious discrepancies of opinion concerning the mutual relations and the geological age of the strata which compose it.

Among the difficulties which confront the investigator of the order of succession in these fluvo-marine strata of the Hampshire basin, the most serious is found in the tendency shown by the various members of the formation to undergo rapid variations in mineral characters within short distances. As in the Wealden and other similar deposits formed in deltas, so here, we find the whole mass of strata made up of lenticular patches of sediment dovetailing into one another in the most complicated manner; so much, indeed, is this the case, that we seldom discover any bed in the whole formation exhibiting such persistency of character as to allow of its being traced over any considerable area. Hence the art of the geological surveyor and map-maker—which, in dealing with the more uniformly deposited marine strata, often affords such valuable aid in making out the order of succession of beds—is here comparatively useless. And the perplexities of the geological surveyor are greatly increased by the fact that all over the northern half of the Isle of Wight and the New Forest, where these strata are developed, thick superficial deposits of sand and gravel almost everywhere conceal the underlying Tertiaries from our view.

Although additions to our knowledge of the fauna and flora of these beds have been made by the examination of such isolated exposures as are to be found in railway-cuttings, brick-pits, quarries, and wells, yet, in seeking to determine the relations of the several beds to one another, we are obliged to fall back upon the more extensive and continuous sections exhibited in the sea-cliffs; and it is a fortunate circumstance that these coast-sections are both numerous and well exposed.

It may be readily believed, too, that the frequent repetition of beds deposited under similar conditions, and therefore presenting identical mineral characters, will be a fruitful source of error, unless the aid of the palæontologist be constantly invoked to enable us to identify the several members of the formation by their organic remains. And the geologist must be prepared to avail himself to the fullest extent of the researches of investigators of strata of equivalent age in other areas, where important light may be thrown upon the order of appearance of the forms of organic life which occur in our own district.

In my study of these strata, which has occupied me during many years, I have endeavoured to avail myself, as far as possible, of these different kinds of assistance. Moreover, in my examination of the positions and relations of the strata, I have been greatly aided by the publication of the admirable 6-inch and 25-inch maps of the Ordnance Survey, which supply us with the means of plotting the cliff-sections in a manner which was not possible at the time when the geological survey of the island was made, when no Ordnance map existed, except the obsolete and incorrect 1-inch map of 1810. I will now briefly enumerate the conclusions to which I have been led by these studies.

The strata exposed at the base of Headon Hill, at the western extremity of the Isle of Wight, are not, as supposed by previous observers, a mere repetition, through an anticlinal fold, of the beds seen in Colwell and Totland Bays, but are on a distinct and lower horizon than the latter. These Headon-Hill beds are also found to contain a different assemblage of fossils from that which characterizes the Colwell- and Totland-Bay beds. I shall show that this new reading of the succession of strata in the Hampshire basin harmonizes much better with the order established by foreign geologists and palæontologists than does the one usually accepted. Indeed it will be made apparent, as the result of this investigation, that the sequence of beds in this country agrees most closely with that of the equivalent Middle Tertiary strata in France, Belgium, and Northern Germany. Finally, it will be proved that the thickness and importance of this series of strata is much greater than has hitherto been supposed, attaining to not less than 800 or 900 feet; and it will be shown to belong to the lower division of a great system of strata, which is represented, both in Europe and North America, by deposits of enormous thickness, everywhere characterized by large and distinctive faunas and floras.

II. History of Previous Opinion.

The foundation of our knowledge of the succession of the Tertiary strata in Western Europe was laid by the publication, in the year 1808, of Cuvier and Brongniart's 'Essai sur la Géographie Minéralogique des Environs de Paris.' It was through the study of this work that Webster, who had already collected much valuable topographical information concerning the beds exposed on the coasts of the Isle of Wight, Hampshire, and Dorsetshire, was enabled to classify those fluvio-marine beds, with which we are now particularly concerned, and to point out their equivalents among the strata of the Paris basin. It would appear that Webster found in the Museum of this Society a collection of fossils procured from the neighbourhood of Paris by Count de Bournon; and on a comparison of these with the series of organic remains which he had himself obtained from the several divisions of the Isle-of-Wight strata, he was greatly impressed with their general resemblance. So interested was he, indeed, by this discovery, that, without waiting for the advent of more favourable weather, he set out in midwinter to re-examine the Isle-of-Wight sections, with the aid of the new clue which he had obtained. The result of this investigation he gave to the world in his twelfth and concluding letter addressed to Sir Henry Englefield on February 11th, 1813*.

Cuvier and Brongniart had divided the Tertiary strata of the Paris basin into five groups; and it was with the upper three of these that Webster correlated the fluvio-marine beds of the Hampshire basin. Hence arose the division of the Isle-of-Wight fluvio-marine beds into a "Lower Freshwater Formation:" a "Middle Marine Formation," and an "Upper Freshwater Formation:" and this classification long held its ground; for it seemed to find support in the fact that at many points marine strata might be observed with freshwater beds lying both above and below them.

But subsequent observations, especially those of M. Constant Prévost, demonstrated that the simple classification of Cuvier and Brongniart did not hold good, even for all parts of the Paris basin; while Mr. Prestwich's researches in this country proved that Webster and those who followed his views, in seeking to bring into exact agreement the succession of beds in the Paris and Hampshire basins respectively, had confounded together deposits as distinct from one another as the London, Bracklesham, and Barton Clays.

With respect to the fluvio-marine beds, however, Webster's threefold division long held its ground, and was unhesitatingly accepted by all geologists. The researches of Sedgwick, Lyell, Bowerbank, Mantell, and others added many new facts to the stock of information acquired concerning these beds; while the important discovery that they contain a mammalian fauna similar to that of the gypsum of Montmartre (which discovery was made by Dr. Buckland

* 'A Description of the Principal Picturesque Beauties, Antiquities, and Geological Phenomena of the Isle of Wight,' by Sir Henry Englefield, Bart. (London, 1816), p. 226.

in 1825*, and fully confirmed by Mr. S. P. Pratt in 1835†, and by Prof. Owen in 1841‡), established the fact of their general parallelism with the upper portion of the series seen in the Paris basin.

The first step towards the rectification of the classification of the fluvio-marine strata was made by Mr. Prestwich in the year 1846. In a short but very suggestive and valuable paper§, he showed that at Hamstead and Bouldnor Cliffs, in the Isle of Wight, there occurs a series of estuarine and freshwater deposits, which he regarded as overlying the whole fluvio-marine series, and which contains, as he pointed out, a fauna of distinct character from that of the underlying beds.

Although many details concerning the several strata were observed and described in succeeding years by Mr. Searles V. Wood, Dr. Wright, and the Marchioness of Hastings, both in the Isle of Wight and on the opposite coast of Hampshire, while great additions were made to our knowledge of the reptilian and mammalian fauna by these and other authors, yet no new step in advance was made in the classification of these beds till Edward Forbes turned his attention to the subject in the year 1852. In the meanwhile the difficulty of harmonizing the accepted classification of the Hampshire beds with the divisions established by accurate observers in various parts of the Continent was strikingly illustrated by the discordant results arrived at by such able students of Tertiary geology as Constant Prévost‖, d'Archiac¶, Dumont**, and Hébert††.

Forbes's careful study of the relations of the beds exposed in the cliff-sections of the Isle of Wight, combined with his thorough and critical examination of the fossils collected at different horizons, enabled him to establish two very important points. In the first place, he confirmed Mr. Prestwich's determination that the strata exposed at Hamstead and Bouldnor Cliffs overlie and are of younger age than all the other strata of the fluvio-marine series. For this upper series of strata, which he showed to contain a very distinct and characteristic assemblage of fossils, Forbes proposed the name

* "On the Discovery of *Anoplotherium commune* in the Isle of Wight. By the Rev. Prof. W. Buckland," Ann. of Phil. ser. 2, vol. x. p. 360.

† "Remarks on the Existence of the *Anoplotherium* and *Palæotherium* in the Lower Freshwater Formation at Binstead, near Ryde, in the Isle of Wight. By S. P. Pratt," Trans. Geol. Soc. ser. 2, vol. iii. p. 451.

‡ "Description of some Fossil Remains of *Chœropotamus*, *Palæotherium*, *Anoplotherium*, and *Dichobune* from the Eocene Formation, Isle of Wight. By Prof. R. Owen," Trans. Geol. Soc. ser. 2, vol. vi. p. 41.

§ "On the Occurrence of *Cypris* in a part of the Tertiary Freshwater Strata of the Isle of Wight," Rep. Brit. Assoc. for 1846, Trans. of Sections, p. 56.

‖ "Coupe d'Alum Bay et d'Headen-Hill, dans l'île de Wight," Bull. Soc. Géol. France, t. viii. p. 76.

¶ "Note sur les Sables et Grès Moyens Tertiaires," Bull. Soc. Géol. France, t. ix. p. 54.

** "Essai sur la co-ordination des terrains tertiaires du Nord de la France, de la Belgique, et de l'Angleterre," Bull. Soc. Géol. France, t. x. pp. 158, 168.

†† "Comparaison des Couches tertiaires inférieures de la France et de l'Angleterre," Bull. Soc. Géol. France, sér. 2, t. ix. p. 350.

of the "Hempstead Series"*. In the second place Forbes demonstrated, by both stratigraphical and palæontological evidence, that the thick freshwater limestones seen at Bembridge Ledge and in Headon Hill respectively, are not, as had been supposed by all previous writers on the subject, on the same horizon, but that the former of these belongs to a much more recent period than the latter.

As the result of his observations of the strata and study of their fossils in 1853, Edward Forbes proposed the total abandonment of Webster's classification, and the division of the fluvio-marine strata of the Isle of Wight into four series—the Headon, the Osborne and St. Helens, the Bembridge, and the Hempstead†. This is the classification which was adopted in the publications of the Geological Survey, and is now generally received among geologists.

Unfortunately, Edward Forbes's life was not spared sufficiently long to enable him to complete his study of this important formation. While his observations on the three higher divisions of the formation are very full and detailed, it is evident, from an examination of Forbes's posthumous work, that he had been able to devote far less attention to the study of the succession of beds and the fossils of the lowest or Headon series. With regard to these strata Forbes maintained, as almost all previous observers had done, that the beds of Colwell and Totland Bays are on the same horizon as those at the base of Headon Hill and at Hordwell Cliff.

It will be seen that Webster made the mistake of placing all marine bands in the fluvio-marine formation upon one horizon. Prestwich made the first rectification of this error by proving that the Hamstead strata are superior to all the other fluvio-marine strata; and Forbes followed in the same direction, by showing that the oyster-beds of Bembridge are on a distinct and much higher horizon than those of either Colwell Bay or Headon Hill. I shall now demonstrate that the Colwell-Bay marine beds are not, as has hitherto been supposed, the equivalent of those of Headon Hill and Hordwell Cliff, but that they occupy a distinct and much higher horizon.

Since Edward Forbes's premature removal from our midst, very great and important additions have been made to our knowledge of the fauna and flora of the fluvio-marine beds of the Hampshire basin. To no one do we owe more for valuable additions to our knowledge of the palæontology of this formation than to the late Mr. Frederick E. Edwards and Mr. S. V. Wood‡, who have collected and described

* In the choice of this name Forbes was singularly unfortunate. The name of the farm near which the beds are exposed is "Hamstead," though it is misprinted "Hempstead" on the old 1-inch map of 1810. This name, as it now stands, is not only quite unknown in the Isle of Wight, but runs the risk of being confounded with localities in Essex and Hertfordshire.

† "On the Fluvio-marine Tertiaries of the Isle of Wight," Quart. Journ. Geol. Soc. vol. ix. p. 259; "On some new Points in British Geology," Edin. New Phil. Journ. vol. lv. p. 263.

‡ 'A Monograph of the Eocene Mollusca, Cephalopoda and Gasteropoda,' by F. E. Edwards, supplemented by S. V. Wood; 'Bivalves,' by S. V. Wood. Palæontographical Society, 1848–1877.

so many of the fossils of the Lower Tertiary formations. Owing to their labours and those of other indefatigable collectors, the number of known fossil forms from the fluvio-marine beds is at least four times as great as was recognized by Edward Forbes.

At the same time the remarkable fauna of Brockenhurst, in the New Forest, which was discovered by Mr. Edwards, has been carefully studied by Von Könen* and Dr. Duncan†, who have shown the exact agreement of this fauna with that of the Lower Oligocene in Northern Germany; while the Rev. Osmond Fisher‡ and Mr. H. M. Jenkins§ have recognized its identity with that of certain strata in the Isle of Wight.

Last, but not least, must be mentioned the great advances which have been made in our knowledge of the faunas of equivalent strata upon the continent of Europe, especially those which we owe to the researches of Deshayes in the Paris basin, of Sandberger in the Mayence basin, and of Hörnes in the Vienna basin, which have supplied valuable means of comparison between the English and foreign strata, such as were almost wholly wanting when Forbes was engaged in the study of the Isle-of-Wight beds. Furthermore, many able geologists, among whom may especially be mentioned M. Hébert in France, MM. Charles Mayer and Renevier in Switzerland, MM. Sandberger and Beyrich in North Germany, and M. T. Fuchs in Austria, have occupied themselves with the question of the correlation of the various European Tertiary deposits with great success.

Under these circumstances we are now supplied with the means for making a much more exact and rigid comparison of the strata of the Hampshire basin with those of the other European areas than was possible twenty-five years ago. Foreign geologists, who have endeavoured to correlate the British deposits of this age with their equivalents on the continent, have experienced the greatest difficulties, owing, as I believe, to the succession of beds in this country having been hitherto misunderstood. It is on these grounds that I venture to offer a new classification of these strata as the result of researches which I have carried on for some time past.

III. Stratigraphical Evidence.

We have stated that hitherto a serious error has been made in reading the succession of strata exposed in the cliff-sections at the western extremity of the Isle of Wight. The beds seen at Colwell and Totland Bays have been regarded by nearly all observers as being upon the same geological horizon as those exposed at the base of Headon Hill, whereas, as I shall now proceed to show, the latter altogether underlie the former. The primary cause of this mistake concerning the succession of these beds is not difficult to discover.

* "On the Correlation of the Oligocene Deposits of Belgium, Northern Germany, and the South of England," Quart. Journ. Geol. Soc. vol. xx. p. 97.

† 'A Monograph of British Fossil Corals,' 2nd series, Palæontographical Society, 1866.

‡ Quart. Journ. Geol. Soc. vol. xviii. p. 67, footnote.

§ Quart. Journ. Geol. Soc. vol. xxiv. p. 519.

Almost every geologist who has studied the section in question has assumed the existence of a great anticlinal fold, of which the summit is supposed to be seen in Totland Bay; and as the effect of this great flexure, the strata seen at the base of Headon Hill are supposed to be repeated, with an opposite dip, in Colwell and Totland Bays. The manner in which this supposed anticlinal is regarded as having affected the strata is illustrated in Prof. Edward Forbes's memoir (see Pl. VII. fig. 1), and also in Sheet 47 of the Horizontal Sections published by the Geological Survey.

The circumstance which seems to have given rise to this correlation in the first instance was the occurrence, both at Colwell Bay and at the base of Headon Hill, of a band containing numerous oysters and other marine shells, and especially characterized by abundant and well-preserved specimens of *Cytherea incrassata*, Sow. Now the "Venus-bed," as it was called by collectors, so well seen in Colwell Bay, soon came to be identified with that at the base of Headon Hill; and the term "Middle Headon" was applied to both. At the same time the freshwater beds, lying respectively above and below these marine bands, were correlated with one another and termed "Upper" and "Lower Headon."

But *Cytherea incrassata*, Sow., is not by any means to be regarded as an eminently characteristic shell marking a particular geological horizon. According to the Geological Survey, it makes its first appearance in the Barton Clay, and ranges up certainly as high as the Bembridge Marls. As I shall show hereafter, the "Venus-bed" of Colwell Bay contains a very different fauna from that at the base of Headon Hill. A third "Venus-bed" is found in the midst of the Bembridge series; and the failure of geologists, prior to the work of Edward Forbes, to discriminate between this and the other "Venus-beds" led to the Headon strata being placed on the same horizon as the Bembridge.

This correlation of the "Venus-beds" of Colwell Bay and Headon Hill has been productive of a great amount of confusion, as will soon be made apparent when we critically examine the conclusions of different authors who have written upon the subject. As early as the year 1821 Mr. G. B. Sowerby pointed out that the so-called marine bed of Headon Hill had little claim to be so regarded; for the number of freshwater forms found in it is so great that it can only be considered as having been deposited under estuarine conditions. Sedgwick, who reexamined the sections in the following year, seems to have clearly perceived the points of difference between the beds in Colwell Bay and in Headon Hill.

Both Edward Forbes and Mr. Bristow appear to have experienced the greatest difficulties in their attempt to correlate with one another the beds above and below the "Venus-beds" of Colwell Bay and Headon Hill respectively. Thus they found it necessary to assume that the beds called "Upper Headon" at Colwell Bay have suddenly expanded within a distance of less than two miles from 49 feet to 85 feet; while the thick beds of limestone which are so conspicuous in the latter locality are entirely wanting in the former. The difficulties felt by the geological surveyors are brought out very prominently if we carefully compare the several publications which they have issued at successive dates. Thus, in the sections prepared to illustrate the memoir published in 1856*, 48 feet of strata, which in the text of the memoir are described as belonging to the "Osborne and St. Helen's Series," are placed in the "Upper Headon;" but in the sheet of 'Vertical Sections,' issued in 1858†, the first reading is adopted, while in the general memoir on the Isle of Wight, which appeared in 1862‡, a return is made to the second reading. A comparison of these several publications of the Geological Survey must lead every one to the conclusion that, by the assumption of the identity of the marine beds at Colwell Bay and Headon Hill, the authors of these works had been led into inextricable difficulties and confusion. All these difficulties are removed when we recognize the fact that the Colwell- and Totland-Bay beds altogether overlie those exposed at the base of Headon Hill.

There are not wanting indications, however, that several authors were almost upon the point of recognizing the true succession of beds at the western extremity of the Isle of Wight. Thus Dr. Wright, in his admirable section of the strata between Cliff End and Headon Hill§, clearly points out that the Limnæan limestone of How Ledge, and the sandy rock of Warden Point, are distinctly recognizable high up in the north-eastern face of Headon Hill. This being the case, it is clear that the "Venus-bed" and Oyster-bands of Colwell Bay, which are undoubtedly *above* the Limnæan limestone and sandy rock, cannot possibly be represented by the brackish-water beds which occur just above the sea-level in the same part of Headon Hill. Unfortunately, however, Dr. Wright did not follow up this important clue to the true succession of beds which he had discovered, but permitted himself to be carried away by the usually accepted opinion that there exists only one marine stratum with freshwater deposits above and below it.

Dr. Wright's valuable observations were published in 1851; and in the year following Prof. Hébert declared his conviction, as the result of a personal examination of the Isle-of-Wight sections, that the Colwell-Bay beds are upon an altogether higher horizon than those of Headon Hill. Prof. Hébert, whose exact acquaintance with the Lower Tertiaries of the Paris basin lends the greatest weight to his opinions, pointed out that the marine beds of Headon Hill and Hordwell Cliff contain precisely the same fauna as "the upper fossiliferous zone of Mortefontaine, Monneville," &c., while the Colwell-Bay beds agree in their fossils with the lower part of the Fontaine-

* Mem. Geol. Surv. 'On the Tertiary Fluvio-marine Formation of the Isle of Wight,' by Prof. Edward Forbes, F.R.S. Compare plate 10 and p. 81.

† Vertical Sections, Geol. Survey, sheet 25.

‡ Mem. Geol. Surv. 'The Geology of the Isle of Wight' (sheet 10), by H. W. Bristow, F.G.S., plate 4.

§ "A Stratigraphical Account of the Section from Round-Tower Point to Alum Bay, on the North-west Coast of the Isle of Wight," by Dr. T. Wright, Ann. and Mag. Nat. Hist. ser. 2, vol. vii. p. 14, and Proc. Cotteswold Nat. Club, vol. i. p. 87.

bleau Sands. Hence the distinguished French geologist argued that Colwell-Bay beds are of younger age, and must overlie those of the Headon Hill and Hordwell*. Unfortunately some of the points of correlation insisted upon by M. Hébert in the same paper, were such as could not be accepted by English geologists (and this was forcibly pointed out by Lyell and Forbes); thus the really valuable suggestions made by the French geologist came to be altogether neglected by later writers upon the subject in this country.

Although I was led to the recognition of the true succession of beds in the Isle-of-Wight section quite independently of these observations of Dr. Wright and M. Hébert, it is right to point out how near these geologists were to the true solution of the problem. I may add that I am convinced that although Prof. Edward Forbes argued so strongly against the views of M. Hébert, yet before his death he had begun to perceive the difficulties which beset the accepted classification of the Headon beds, and that, had his life been spared to complete that rigid palæontological examination of the lower beds of the fluvio-marine series which he so successfully accomplished with respect to the higher parts of the same series, he would have so modified his classification as to have rendered the publication of the present memoir unnecessary. In Forbes's posthumous memoir the account of the Headon beds occupies only three pages, which are reprinted, almost without alteration, from the memoir read before this Society by the author on the 4th of May, 1853†.

If we now proceed to examine the supposed proofs of the existence of a great anticlinal by which the strata at the base of Headon Hill are folded over so as to reappear in Colwell Bay, we shall find that they do not stand the test of careful scrutiny and exact measurement. Webster and other authors following him have well shown how the Tertiary and underlying strata of the Isle of Wight have been subjected to disturbances producing a series of flexures, the axes of which lie in an east-and-west direction, and which attain their maximum development in the great anticlinal curve stretching from Whitecliff Bay to Alum Bay and thence on to Studland Bay on the Dorsetshire coast. But, in addition to these east-and-west folds, the Isle-of-Wight strata exhibit evidence of having been subjected to another set of flexures, at right angles to the former, and having their axes striking north and south. The positions and effects of this second series of flexures were well illustrated by Prof. Edward Forbes in his memoir read before this Society ‡.

Now, from Cliff End to Headon Hill, the coast of the Isle of Wight trends nearly north and south, and we have presented to us in the cliffs a section nearly at right angles to the first-mentioned series of folds. From Cliff End to Warden Point the beds have a steady dip of from 2° to 3° to the north, interrupted only by several

* "Comparaison des couches tertiaires inférieures de la France et de l'Angleterre," Bull. Soc. Géol. France, 2e ser. t. ix. p. 191.

† Quart. Journ. Geol. Soc. vol. ix. p. 259.

‡ Quart. Journ. Geol. Soc. vol. ix. p. 260, fig. 1.

slight dislocations and a small series of contortions. 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. The great mural face of Headon Hill, however, has a trend almost at right angles to that of the cliffs of Colwell and Totland Bays; and the section exposed on the face of the hill is nearly at right angles to the *second* series of flexures which have been indicated as affecting the Isle-of-Wight beds. These strata seen in Headon Hill have a slight dip to the west. Passing round Heatherwood Point we again find the cliffs assuming a northerly and southerly trend, and the beds are found dipping to the north, at an angle which increases very rapidly, till at Alum Bay the strata assume a vertical position, and near the Chalk are for a short distance actually inverted.

Now, when these Isle-of-Wight cliffs are viewed from the sea, the great changes which take place in the trend of the coast may be easily overlooked; and undoubtedly the first impression which is made upon the mind of an observer is, that there exists a great anticlinal flexure, the summit of which is seen in Totland Bay, and that the Colwell-Bay and Headon-Hill beds respectively lie in equivalent positions on either side of this axis, and are therefore representatives the one of the other.

If, however, instead of trusting to the general impression which is produced by viewing these beds from a distance, we carefully plot the section to scale by the aid of the admirable 25-inch maps of the Ordnance Survey, allowing carefully for the changes in direction of the cliffs, we shall find that the effect produced by the Totland-Bay anticlinal has been very greatly overrated, and that, in consequence of this, the true order of succession of the beds has been altogether misunderstood. The strata of How Ledge and Warden Point are seen in such a true-scale section (Pl. VII. figs. 1, 2, & 3) to be clearly continued in precisely similar beds appearing underneath the gravel of Headon Hill; the clays beneath are found to be a continuation of those seen in Totland Bay; while all the underlying strata are recognized as distinct from and on a lower horizon than those exposed in the bays to the north of Headon Hill.

When we come to compare the succession and thickness of the several strata exposed in Headon Hill and in the bays to the northwards, the correctness of this new reading of the section will become strikingly apparent. The two series of beds can only be correlated with one another, as has been attempted by previous observers, by supposing that in the distance of a mile or two the most remarkable changes have taken place, both in the mineral character and the fossil contents of the several beds. But if, on the other hand, we admit that the lowest beds in Totland Bay are represented in the higher part of the Headon-Hill section, while the main part of the strata at that locality are on a different and lower horizon, the difficulties and discrepancies will at once disappear.

Fortunately, however, I am able to adduce proofs of the most convincing kind of the correctness of the reading of these sections which I now offer. If, as is supposed by the earlier interpretation, the strata of Colwell and Totland Bays be only a repetition of those of Headon Hill, resulting from the presence of a great anticlinal flexure, then the well-marked white sands of Headon Hill ought to be found near the summit of the anticlinal in Totland Bay. In this position they are actually represented as occurring, in both the longitudinal and vertical sections of the Geological Survey *, it being supposed that they are concealed by heavy masses of talus which cover that portion of the cliffs. Now within the last few years excavations have been made at this locality for the purpose of erecting the new reading-rooms; and it is found that the Headon-Hill Sands do not occur in the position indicated by the Geological Survey, but that beds are found which have their exact counterpart in the Headon-Hill section, not at the base, but at a much higher part of the series. I looked forward with great interest to the opening of these sections in Totland Bay, as enabling me to apply a crucial test to the two interpretations of the section; and the results are such as to remove any possibility of doubt upon the subject.

Again, the position of the Bembridge Limestone at Headon Hill quite agrees with the interpretation of the section which I now offer, but is altogether irreconcilable with that which has hitherto been adopted. It is admitted on all hands that at the north-east angle of Headon Hill the marine band ("Middle Headon beds") makes its appearance just above the sea-level. Now the excellent maps of the Ordnance Survey enable us to fix with the greatest precision the height above the sea-level of the Bembridge Limestone, which is so well exposed with all its characteristic fossils near the cottage on the Warren. We thus learn that 250 feet of strata must intervene between the Bembridge Limestone and the marine band of Headon Hill; but the Geological-Survey 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. Hence, if we believe that the marine bed at Headon Hill is identical with that at Colwell Bay, we must suppose 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 characters. But 250 feet of strata is precisely the thickness required by my interpretation. It may be objected that the marine beds of Colwell Bay have never been detected in the upper part of the Headon-Hill section, where they must exist according to my view. But those who know the manner in which the succession of beds is obscured in the upper part of Headon Hill, through land-slips and the great capping of gravel, will feel little surprise that this particular bed has never been seen there.

In the two diagrammatic sections on Plate VII. the two readings of the succession of strata, as seen at the western end of the Isle of Wight, are illustrated. Fig. 1 is exactly copied from the diagram

* Horizontal Sections, sheet 47; Vertical Sections, sheet 25.

given by Prof. Edward Forbes in his memoir on the Tertiary Fluvio-marine Formation of the Isle of Wight (p. 89). In fig. 2 the relative heights are given in accordance with the measurements of the Ordnance Survey; but the vertical scale is different from the horizontal; and the section illustrates diagrammatically the view of the succession of beds which I now put forward. The section fig. 3 on the same Plate is drawn upon the true scale, both vertical and horizontal, the heights and distances being taken from the new maps of the Ordnance Survey.

IV. Palæontological Evidence.

I shall now proceed to show that the palæontological evidence in favour of the correlation which I propose is not less complete and satisfactory than the stratigraphical. According to the usually received interpretation, a series of marine strata 100 feet thick in Whitecliff Bay, the well-known and distinctly marked marine beds of Colwell Bay, and the marine beds of the New Forest exposed at Brockenhurst, Roydon, and Lyndhurst are represented at Headon Hill by the brackish-water Middle Headon beds, and at Hordwell Cliff by a band a few inches thick, containing both marine and freshwater forms.

But against this correlation several very serious objections may be urged. In the first place, it must be noticed that at Whitecliff Bay, at Colwell Bay, and in the several New-Forest localities, the strata are of *purely marine* origin, and contain no admixture of freshwater shells, while in the last-mentioned reef-building corals abound*, and to the existence of these an influx of fresh water is known to be highly inimical. The so-called "Middle Marine" beds of Headon Hill and Hordwell Cliff are of totally different character, exhibiting clear evidence of the prevalence of estuarine or brackish-water conditions only. At both localities we find some shells belonging to marine genera, such as *Ancillaria*, *Arca*, *Bulla*, *Cancellaria*, *Chemnitzia*, *Corbula*, *Cytherea*, *Fusus*, *Lucina*, *Murex*, *Natica*, *Nucula*, *Ostrea*, *Pleurotoma*, *Psammobia*, *Scalaria*, and *Voluta*, with Balani and Serpulæ. But these marine forms are almost always dwarfed in size, and exhibit clear evidence of having lived under unfavourable conditions; while mingled with them we find shells belonging to genera which usually frequent brackish water, such as *Cerithium*, *Cyrena*, *Hydrobia*, and *Odostomia*, with other purely freshwater forms, such as *Limnæa*, *Melania*, *Melanopsis*, *Potamomya*, and *Planorbis*.

The marine beds of Whitecliff Bay attain a thickness of 100 feet; at Colwell Bay they are about 25 feet; while in the New Forest their entire thickness, although it has never been determined, is probably very considerable. These beds contain a very large and

* See the important memoir by Dr. Duncan "on the Physical Geography of Western Europe during the Mesozoic and Cainozoic Periods, elucidated by their Coral Faunas," Quart. Journ. Geol. Soc. vol. xxvi. (1870), p. 51.

varied marine fauna, which, as I shall hereafter show, characterizes a higher horizon in the geological series as displayed upon the Continent than is represented by the brackish-water fauna of Headon Hill and Hordwell Cliff.

Now, although in such series of strata as those of the Isle of Wight we might be prepared to find marine beds passing at certain points into others exhibiting evidence of brackish-water conditions, yet it is impossible to believe that a thick mass of marine strata, maintaining such a uniformity of character and of fossils at points so distant as Whitecliff Bay, Colwell Bay, and Brockenhurst, could lose all their distinctive characters and pass into brackish-water strata at intermediate points like Headon Hill and Hordwell Cliff. Moreover, as I shall proceed to show, the marine fossils of these two sets of beds are not identical in character, as has been supposed, but very distinct, the faunas being such as, at many points upon the Continent, characterize two perfectly distinct horizons.

This distinction between the fauna of the Colwell-Bay beds and that of the Headon-Hill and Hordwell-Cliff beds is rendered strikingly apparent if we direct our attention to the species and varieties by which certain genera are represented in these two deposits. The genus *Cerithium* especially affords very interesting and valuable evidence bearing on this point; and it was, indeed, while engaged in a series of researches, commenced many years ago, with a view to the determination of the genealogy and lines of descent of the forms of this group, that I first detected the serious errors which have crept into our classification and correlation of the strata we are now considering. While the form now known as *Cerithium pseudocinctum*, d'Orb. (with its variety *C. trizonatum*, Morris) occurs in great abundance both in the marine beds of Colwell Bay and all through the Headon series, two well-marked forms, *Cerithium ventricosum*, Sow., and *C. concavum*, Sow. (with its varieties *C. pleurotomoides*, Lam., and *C. rusticum*, Desh.), are entirely confined to the Headon beds, occurring similarly at Hordwell Cliff. At both these latter localities these two forms of *Cerithium* are found in such prodigious abundance as to constitute the most characteristic fossils of the beds; and their total absence from the Whitecliff-Bay, the Colwell-Bay, and the New-Forest beds is a most significant circumstance.

Now, as long ago shown by M. Hébert, the form of *Cerithium* known in this country as *C. concavum*, Sow., and in France as *C. rusticum*, Desh., and *C. pleurotomoides*, Lam., is found at a very definite horizon in the Paris basin—"the Upper fossiliferous zone of Mortefontaine and Monneville &c."—the beds there, like those of Headon Hill, being characterized by the extreme abundance of that fossil. More recently Dr. C. Mayer, of Zurich, whose researches have contributed greatly to our knowledge of the exact correlation of the various Tertiary deposits, has insisted upon the importance of this palæontological horizon, which he has distinguished by the name of "the Zone of *Cerithium concavum*"*. Dr. Sandberger, too, fully

* C. Mayer, 'Table des Terrains Tertiaires Inférieurs,' Zürich, 1875.

indorses the opinion of Hébert and Mayer as to the distinctness and importance of this division of the Lower Tertiary series.*

When we come to study the whole of the marine forms of Headon Hill and Hordwell, and to compare them with those of the Brockenhurst, Colwell-Bay, and Whitecliff-Bay beds, the distinction of the two faunas becomes strikingly apparent. Nearly one hundred marine forms are known from Headon Hill and Hordwell, while almost twice that number have been obtained from the New-Forest localities, Colwell Bay, and Whitecliff Bay. Of the forms found at Headon Hill and Hordwell Cliff, less than one half occur at the three other places. Again, if we compare both of the marine faunas with that of the Barton series, we 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 Bay are found at Barton. On the other hand the latter fauna has more species in common with that of the Hempstead beds than has the former.

Summing up the results of this palæontological examination of the beds, we find that the fossils in the Headon-Hill and Hordwell-Cliff beds are almost identical, while those of Colwell Bay, Whitecliff Bay, and of the New Forest localities also present the very closest agreement with one another. But when we come to compare the fauna of the two first-mentioned places with that of the other three, we are struck by remarkable points of difference. In the first place, the conditions indicated by the former are estuarine, of the latter purely marine; secondly, more than one half of the forms found in the former are different from those in the latter; thirdly, the former exhibits a much closer approximation to the Barton fauna than does the latter; and, fourthly (and most important of all), the fauna of the former agrees with that of a series of beds occurring both in France and Germany, which unquestionably underlie and are of older date than beds containing the fauna of the latter. We thus see that the palæontological evidence fully supports the conclusion derived from a study of the physical evidence—namely, that the Hordwell-Cliff and Headon-Hill strata are not, as has previously been supposed, on the same horizon with those of Brockenhurst, Colwell Bay, and Whitecliff Bay, but occupy a distinct and lower place in the geological series.

V. Correlation of the Strata with Foreign Deposits.

Since the date of the appearance of Edward Forbes's posthumous monograph 'On the Tertiary Fluvio-marine Formation of the Isle of Wight,' so much has been done in the investigation of the faunas and floras† of the several divisions of the series, and at the same

* Sandberger, 'Land- u. Süsswasser-Conchylien der Vorwelt,' p. 198.

† The valuable collection of Lower Tertiary fossils made with such untiring industry by the late Mr. F. E. Edwards, and in part described by himself, Mr. S. V. Wood, and Dr. Duncan in the publications of the Palæontographical Society, have fortunately been acquired for the nation, and are now in

time so vast a fund of new information has been accumulated concerning the age and relations of the equivalent beds upon the Continent, that geologists are now in a very different, and far more favourable, position for estimating the evidence concerning the correlation of the various beds than was the case at the time of Edward Forbes's death in 1854. This circumstance, taken in connexion with the fact which I have now established, viz. the error hitherto made in the determination of the order of succession of the beds, affords sufficient warrant for that revision of the classification and nomenclature of the beds in question which I now propose to make.

As Professor Huxley has well pointed out, the time is approaching when geologists will have to establish two distinct and parallel systems of classification, for the formations of marine and freshwater origin respectively. In the series of beds which we are now considering, we have such remarkable alternations of marine and freshwater conditions that it will be of advantage to consider the evidence afforded by the study of the marine fauna, and by the freshwater and terrestrial fauna and flora respectively. The earliest classification of the Tertiary strata—that of Lyell—was based entirely upon the study of the marine Mollusca; and these forms still constitute the safest guides in correlating the beds over different areas; but, at the same time, so much attention has of late years been devoted to the study of the freshwater and terrestrial shells (the results of which have been admirably embodied in Dr. Sandberger's 'Die Land- und Süsswasser-Conchylien der Vorwelt'), that great assistance may be obtained from these forms in the comparison of the strata in different areas. Lastly, the flora and vertebrate fauna occupying the land of the period afford the means of a third series of comparisons. We shall proceed to the study of each of these three kinds of evidence, in the order in which we have enumerated them, which is the order of their respective importance.

Confining our attention in the first instance to the forms of marine life, we find that we have three well-marked horizons in the English series which enable us to bring our strata into exact correlation with those of France, Belgium, and Northern Germany, and, less directly, with the deposits of the Alps, the Italian peninsula, and Eastern Europe.

At the base of the Fluvio-marine series lies the richly fossiliferous marine deposit of the Barton Clay. So long ago as 1857, Professor Prestwich was able to enumerate no less than three hundred species of Mollusca from this formation; and when all the known forms contained in the numerous collections in this country come to be described, the number of species from this deposit will probably be found to exceed a thousand.

Now all palæontologists are agreed that the Barton Clay is repre-

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the British Museum. This splendid collection is so admirably arranged that the work of the palæontologist who shall deal with these species is greatly simplified; and it is to be hoped geological literature will soon be enriched by the publication of the as yet undescribed forms by the Palæontographical Society, or, failing this, by the keepers of the national collection.

sented in the Paris basin by the "Sables Moyennes" or "Sables de Beauchamp," and in Belgium by the "Système Laekénien" of Dumont. Most geologists, too, regard this well-marked fossiliferous zone as constituting the highest member of the Eocene or Nummulitic formation. This being admitted, we have an admirable and safely established base-line from which to start in our comparison of the English and foreign representatives of the succeeding geological periods.

Lying upon the Barton Clay we find a great series of estuarine strata, which in places attains a thickness of nearly 400 feet; and this is succeeded by the beds containing the second marine fauna. At Whitecliff Bay these marine beds are 100 feet in thickness; at Colwell Bay they are reduced to 25 feet, while in the New Forest we have evidence that their thickness is considerable, though it has never been exactly determined. Our knowledge of these marine beds in the New-Forest area is derived entirely from an examination of exposures in artificial openings—brickyards, wells, and railway-cuttings. Some of the peculiar fossils of this horizon were obtained so long ago as 1823 by Sir C. Lyell, and by him submitted to Mr. Sowerby for description. Mr. F. E. Edwards made many interesting collections from beds on this horizon at Brockenhurst, Roydon, Whitley Ridge, and Lyndhurst, especially during the period when railway-cuttings were being opened at the first-mentioned of these localities. From information communicated to him by Mr. Edwards, supplemented by his own studies, Von Könen, who was well acquainted with the equivalent beds on the Continent, was enabled to give the account of these beds which was published by this Society in 1864*. Professor P. M. Duncan about the same time described the important coral-fauna of these beds, the distinctive character of which he was the first to recognize.

Now the marine fauna of these beds is a very rich and highly interesting one. Von Könen was able in 1864 to enumerate 56 species of Mollusca as occurring at Brockenhurst; but we are now acquainted with nearly 200 marine forms from the several localities at which the beds representing this horizon occur.

The first point which claims our attention in connexion with this second marine fauna is its striking distinctness from that of the Barton beds. Of the 200 forms which it contains, not more than 20 per cent. are found in the Barton beds. Now this second fauna is found to occur at many points upon the Continent, and always in strata which distinctly overlie the Bartonian deposits. In the Paris basin, it is true, this second marine fauna is not represented; for there the gypsum of Montmartre and other freshwater deposits occur at this horizon, to the exclusion of marine beds; but in Belgium, Northern Germany, and Switzerland we find the exact equivalent of our English strata everywhere containing the same well-characterized fauna. The fossils of the "Tongrien inférieur" of Dumont (the Lower Limburg of Lyell), those of the strata which

* "On the Correlation of the Oligocene Deposits of Belgium, Northern Germany, and the South of England," Quart. Journ. Geol. Soc. vol. xx. p. 97.

over so large a part of North Germany overlie the Brown Coal, and those of the "étage Ligurien" of C. Mayer agree so closely with the forms found in the Isle-of-Wight and New-Forest beds as to put their contemporaneity beyond question. The number of molluscan forms obtained from this horizon at various points on the Continent now greatly exceeds 1000; and everywhere the distinctness of this fauna from that of the Bartonian is not less clearly marked than it is in this country.

Up to the present time, however, the beds which in this country contain this important marine fauna have not received a distinctive local appellation; and as their position in the geological series and their relations to foreign deposits are now fully established, I propose to call them them the "Brockenhurst Series," from the locality in the New Forest at which they have yielded the greatest number of fossils.

The appended list will serve to illustrate the richness and variety of this second marine fauna. I have included in it a number of MS. names given by the late Mr. F. Edwards; for although the forms thus designated have not been described and figured, yet they are so carefully arranged and so accessible for purposes of reference in the British Museum, that I think I am justified in so doing. As to the question whether these forms should be regarded as species or varieties, I hold it to be one of very little importance; enough for us if they can be recognized as presenting constant and distinctive characters, and are found characterizing definite geological horizons.

Fossils of the Brockenhurst Series.

W, found at Whitecliff Bay; C, at Colwell Bay; B, Brockenhurst and neighbourhood; L, Lyndhurst; *x*, pass down into Barton Series; *a*, pass up into Hempstead Series.

x Marginella simplex, *Edw.* C.
x —— æstuarina, *Edw.* B, L.
Voluta tereticosta, *Edw.* MS. W, C.
—— geminata, *Sow.* B, L.
—— spinosa, *Lam.* C, B, L.
x —— decora, *Beyr.* (V. maja, *Edw.*). B, L.
—— suturalis, *Nyst* (V. contabulata, *Edw.*). B.
x —— depauperata, *Sow.* C.
Mitra gracilenta, *Edw.* MS. B.
—— abbreviata, *Edw.* MS. B.
—— polygyra, *Edw.* MS. B.
Conorbis (Conus) dormitor, *Sol.*, var. seminuda, *Edw.* B, L.
—— procerus, *Beyr.* (C. alatus, var. hemilissa, *Edw.*). B, L.
Pleurotoma transversaria, *Lam.* B.
—— ——, var. cymæa, *Edw.* B.
—— ——, var. nana, *Edw.* C.
—— pyrgota, *Edw.* B.
—— bellula, *Phill.* B.
x —— headonensis, *Edw.* C, L.
x —— denticulata, *Bast.* L.
—— ——, var. odontella, *Edw.* C, L.
—— læviuscula, *Edw.* B.
—— subdenticulata, *Goldf.* (P. hantoniensis, *Edw.*). B, L.
Borsonia sulcata, *Rouault.* C.

a Aporrhais (Chenopus) Margerini, *de Kon.*, var. speciosa, *Schloth.* B.
x Rimella rimosa, *Sol.* W, C, B, L.
x Hippocrenes (Rostellaria) ampla, *Sow.* (R. macroptera, *Lam.*). L.
Murex hantoniensis, *Edw.* MS. B, L.
—— sexdentatus, *Sow.* C.
—— ——, var. cinctus, *Edw.* MS. C.
x —— minax, *Sol.* B.
—— obtusus, *Desh.* B.
x Typhis pungens, *Sol.* B, L.
Cantharus subcostulatus, *Edw.* L.
a Pisania (Fusus) labiata, *Sow.* C, B, L.
—— ——, var. concinna, *Edw.* MS. C.
—— nodicosta, *Edw.* MS. B.
—— acuticosta, *Edw.* MS. C.
x Clavella (Fusus) longæva, *Sol.* B, L.
—— ——, var. egregia, *Beyr.* B.
Chrysodomus (Fusus) Sandbergeri, *Beyr.* B.
Leiostoma (Fusus) ovatum, *Beyr.* B.
x Strepsidura (Buccinum) armata, *Sow.* (B. bullatum, *Phill.*). W, B, L.
—— semicostata, *Edw.* MS. C.
x Cominella (Buccinum) deserta, *Sol.* (B. excavatum, *Beyr.*). B.
—— flexuosa, *Edw.* MS. C, B.
—— ventricosa, *Edw.* MS. C.
x Ancillaria buccinoides, *Lam.* C, B, L.
x Cassis ambigua, *Sol.* (C. affinis, *Phill.*). B.
x Natica hantoniensis, *Sow.* B.
—— ——, var. obovata, *Sow.* B.
a —— conulus, *Edw.* MS. B.
—— grossiuscula, *Edw.* MS. B.
—— dubia, *Edw.* MS. B.
—— Studeri, *Bronn.* C, B.
a, x —— labellata, *Lam.* B, L.
Cancellaria pyrgota, *Edw.* MS. (C. sex-muricata, *S. V. Wood*). C, B, L.
—— elongata, *Nyst.* C, B, L.
—— roydonensis, *Edw.* MS. B.
—— scrobicula, *Edw.* MS. B.
x —— evulsa, *Sol.* B.
Pyramidella (Turbonilla?) obscura, *Edw.* MS. B.
Turbonilla plicatella, *Edw.* MS. C, B.
—— semilævis, *Edw.* MS. B.
Odostomia loxodonta, *Edw.* MS. C.
—— subumbilicata, *Edw.* MS. C.
—— geminata, *Edw.* MS. C.
—— multispirata, *Edw.* MS. C.
—— gracilis, *Edw.* MS. C.
—— angustata, *Edw.* MS. B.
Eulima gracillima, *Edw.* MS. C.
Scalaria lævis, *Morr.* C.
—— tessellata, *Edw.* MS. C, B.
Cerithium pseudocinctum, *d'Orb.* W, C, B, L.
—— pyrgotum, *Edw.* MS. C, B.
—— varians, *Edw.* MS. C.
—— subconoideum, *Edw.* MS. C.
—— pliciferum, *Edw.* MS. C.
—— subventricosum, *Edw.* MS. C.
a Nematura parvula, *Desh.* C.
a —— pygmæa, *Forbes.* C.
Trochita (Infundibulum) obliqua, *Sow.* B.
Phorus cretifer, *Edw.* B.
Teinostoma minutissimum, *Edw.* MS. C.
—— micans, *Edw.* MS. C.

Nerita aperta, *Sow.* C.
—— æstuarina, *Edw.* MS. C.
Neritina concava, *Sow.* C.
Tornatella (Actæon) hinnæformis, *Sandb.* B.
—— altera, *Desh.* B.
Orthostoma crenata, *Sow.* B.
—— retiarium, *Edw.* MS. B.
x Ringicula parva, *Edw.* MS. B.
Bulla æstuarina, *Edw.* MS. C, L.
—— Lamarckii, *Desh.* B.
—— curta, *Edw.* MS. L.
—— simillima, *Edw.* MS. L.
—— navella, *Edw.* MS. C.
Cylichna globulus, *Edw.* MS. B.
—— ovalis, *Edw.* MS. C.
Anomia Alcestiana, *Nyst.* B.
Ostrea velata, *S. Wood.* C.
—— ventilabrum, *Goldf.* (O. prona, *S. Wood*). W, C, B, L.
Pecten bellicostatus, *S. Wood.* B.
x Avicula media, *Sow.* B.
Dreissena unguiculus, *Sandb.* B.
Mytilus strigillatus, *S. Wood.* C.
Modiola Nystii, *Kickl.* MS. B.
—— ignota, *Edw.* MS. B.
x Arca biangula, *Lam.* B.
—— appendiculata, *Sow.* W, B.
—— lævigata, *Caill.* C, L.
x —— duplicata, *Sow.* (A. sulcicostata, *Nyst*). B.
Trigonocœlia deltoidea, *Lam.* C, B, L.
Nucula headonensis, *Forbes.* C.
—— nudata, *S. Wood.* B. C.
x —— similis, *Sow.*, var. B.
Leda propinqua, *S. Wood.* C.
—— minima, *Sow.* B.
Cardita simplex, *Edw.* MS. B.
—— paucicostata, *Sandb.* B.
—— deltoidea, *Sow.* W, B, C, L.
—— orbicularis, *Goldf.* B.
x —— oblonga, *Sow.*, var. transversa, *Edw.* MS. B.
Crassatella hantoniensis, *Edw.* B.
Lucina obesa, *Edw.* MS. C.
—— concava, *Defr.* B, C.
—— pulvinata, *Edw.* MS. C.
x —— bartoniensis, *Edw.* MS. B.
x —— Menardii, *Desh.*, var. B.
Strigilla colvellensis, *Edw.* MS. C.
Diplodonta suborbicularis, *Edw.* MS. B.
—— obsea, *Edw.* MS. B.
—— planiuscula, *Edw.* MS. B.
x —— dilatata, *Sow.* B.
x Cardium porulosum, *Lam.* B.
—— obliquum, *Lam.* B.
—— Edwardsii, *Desh.* B.
Protocardium hantoniensis, *Edw.* B.
x Cypricardia pectinifera, *Sow.* B.
Isocardia transversa, *Nyst.* B.
Scintilla angusta, *S. Wood.* C.
Lepton tumidum, *Edw.* MS. C.
Cyprina scutellaria, *Desh.* (*Nyst*). B.
—— Nystii, *Héb.* B.
a, x Cytherea incrassata, *Sow.* sp. W, B, C, L.

Cytherea turgescens, *Edw.* MS. B, L.
—— tumida, *Edw.* MS. B.
—— suborbicularis, *Edw.* MS. B.
—— subelliptica, *Edw.* MS. B.
—— hantoniensis, *Edw.* MS. B.
x —— Solandri, *Sow.* B.
x —— elegans, *Lam.*, var. B.
x Psammobia compressa, *Sow.* (P. stampinensis, *Desh.*). B, C.
—— ——, var. æstuarina, *Edw.* MS. B, C.
—— rudis, *Lam.* (P. solida, *Sow.*). C.
x Sanguinolaria Hollowaysii, *Sow.* L.
a Tellina corbuloides, *Edw.* C.
Syndosmya colwellensis, *Edw.* MS. C.
Mactra filosa, *Edw.* MS. C.
a, *x* —— fastigiata, *Edw.* MS. C.
Mya producta, *Edw.* MS. C.
x Corbula cuspidata, *Sow.* W, C, L.
x —— pisum, *Sow.* L.
Panopæa subeffusa, *Edw.* MS. C.
—— sulculosa, *Edw.* MS. B.
—— corrugata, *Sow.* B.
Clavigella coronata, *Desh.* B.
—— Goldfussi, *Phill.* B.
Fistulana Heyseana, *Phill.* B.
Saxicava, sp. B.
Pholas, sp. B.
Teredo antenautæ? *Sow.* B.
x Balanus unguiformis, *Sow.* B.
Solenastræa cellulosa, *Dunc.* B.
—— Kœneni, *Dunc.* B.
—— Reussi, *Dunc.* B.
—— gemmans, *Dunc.* B.
—— Beyrichi, *Dunc.* B.
—— granulata, *Dunc.* B.
Balanophyllia granulata, *Dunc.* B.
Lobopsammia cariosa, *Goldf.* sp. B.
Litharæa brockenhurstii, *Dunc.* B.
Axopora Michelini, *Dunc.* B.
Madrepora Solanderi, *Defr.* B.
—— Rœmeri, *Dunc.* B.
—— anglica, *Dunc.* B.

Of the 13 species of corals, 4 (namely *Lobopsammia cariosa*, Goldf., *Madrepora Solanderi*, Defr., *Solenastræa Kœneni*, Dunc., and *S. gemmans*, Dunc.) are found in the Oligocene strata of the Continent. I am indebted to Dr. Duncan for valuable information upon this point. It is only right to point out that the study of these corals led Dr. Duncan to the conclusion that the Brockenhurst strata are the representatives of the Oligocene of North Germany, and that this conclusion was arrived at by him quite independently of the work of Von Könen upon the molluscan forms in the same beds.

Separated from the Brockenhurst series by about 300 feet of estuarine and freshwater beds, we find the strata containing our third marine fauna. This fauna is not represented, it is true, by so large a number of species as either the Barton or the Brockenhurst fauna; but we have, nevertheless, sufficient evidence of its distinctness from both of them, and data by which we can correlate the deposits containing this third fauna with beds of the same age upon the Continent. In the upper part of Hamstead (or "Hempstead") and Bouldnor Cliffs in the Isle of Wight, the only point at which the beds of this age are clearly displayed, about 100 species of marine Mollusca have been obtained. The distinction between this fauna and that of the Barton and Brockenhurst series respectively is shown by the fact that at Hamstead only five Barton and twelve Brockenhurst forms occur. Indeed, as was clearly perceived by Lyell, the nearest analogues to the Hempstead fauna are to be found, not in the Eocene deposits, but in the Miocene.

The annexed list of Hempstead fossils sufficiently indicates the character of this fauna; and there cannot be the smallest doubt as to the foreign deposits which must be correlated with the beds containing it. In the Paris basin we have the Lower Fontainebleau Sandstone, in Belgium the Upper Tongrian or Kleyn-Spawen beds, in the Mayence basin and Northern Germany the Marine Sands and Septarian Clay, and in Switzerland the Lower Marine Molasse—each of which contains a fauna presenting so many forms in common with the fauna of the Hempstead beds as to leave no room for doubt as to the approximate contemporaneity of all these deposits.

Fossils of the Hempstead Series.

Voluta Rathieri, *Héb.* (V. Forbesii, *Edw.*).
—— detrita, *Edw.* MS.
Aporrhais (Chenopus) Margerini, *de Kon.*, var. speciosa, *Schloth.*
Cantharus crebricostatus, *Edw.* MS.
Pisania (Fusus) labiata, *Sow.*
—— tricincta, *Edw.* MS.
—— parviuscula, *Edw.* MS.
Chrysodomus (Fusus) Edwardsii, *Mor.*
Cuma (Purpura) monoplex, *Desh.* (C. Charlesworthii, *Edw.*).
Natica conulus, *Edw.* MS.
—— hempsteadensis, *Edw.* MS.
—— labellata, *Lam.*
Turbonilla (Pyramidella) subconvexa, *Edw.* MS.
—— micans, *Edw.* MS.
—— spiculoides, *Edw.* MS.
—— pseudospina, *Edw.* MS.
—— scalaris, *Edw.* MS.
Cerithium plicatum, *Lam.*
—— ——, var. ryssum, *Edw.* MS.
—— ——, var. muticum, *Edw.* MS.
—— ——, var. lineatum, *Edw.* MS.
—— ——, var. immeritum, *Edw.* MS.
—— ——, var. Galeotti, *Nyst.*
—— ——, var. intermedium, *Sandb.*
—— ——, var. papillatum, *Sandb.*
—— subcostellatum, *Forbes.*
—— inornatum, *Mor.* (C. acutum, *Sow.*?).
—— Lamarckii, *Brong.* (C. Sedgwickii, *Mor.*).
—— elegans, *Desh.*
—— ——, var. Austenii, *Forbes.*
—— margaritaceum, *Sow.*
—— submargaritaceum, *A. Braun.*
—— conoidale, *Lam.*
—— venustum, *Edw.* MS.

Cerithium acuminatum, *Edw.* MS.
—— odontolon, *Edw.* MS.
—— asperulum, *Edw.* MS.
—— ligatum, *Edw.* MS.
—— triseriale, *Edw.* MS.
—— asperum, *Edw.* MS.
—— tropis, *Edw.* MS.
—— ornatissimum, *Edw.* MS.
—— cinctum, *Brug.*, var. vectensis, *Edw.* MS.
—— ——, var. conjunctum, *Forbes.*
Rissoa turbinata, *Lam.*
—— diversa, *Edw.* MS.
—— paucicostata, *Edw.* MS.
—— obliquecostata, *Edw.* MS.
Odostomia lineolata, *Sandb.*
—— sulcifera, *Edw.* MS.
—— nitens, *Edw.* MS.
—— micans, *Edw.* MS.
Nematura pupa, *Nyst.*
—— parvula, *Desh.*
—— pygmæa, *Forbes.*
Teinostoma (Adeorbis) decussatum, *Sandb.* sp.
—— subumbilicare, *Edw.* sp.
—— nitidum, *Edw.* MS.
—— affine, *Edw.* MS.
Collonia trigonostoma, *Edw.* MS.
Neritina tristis, *Forbes.*
—— striatula, *Edw.* MS.
—— fulminifera, *Sandb.*
—— marginata, *Edw.* MS.
—— denticulata, *Edw.* MS.
—— planulata, *Edw.* MS.
Tornatella (Actæon) limnæiformis, *Sandb.*
—— fasciolata, *Edw.* MS.
Bulla cælata, *Desh.*
—— Sandbergeri, *Edw.* MS. (B. conoidea, *Sandb.*, non *Desh.*)
—— conoidea, *Desh.*
Ostrea cyathula, *Lam.*
—— callifera, *Lam.*
—— longirostris, *Lam.*
Mytilus affinis, *Sow.*
—— strigillatus, *S. Wood.*
Modiola Prestwichii, *Mor.*
—— flabellula, *S. Wood.*
—— Deshayesii, *Sow.*, var. hempsteadensis, *S. Wood.*
Lithodomus delicatulus, *Desh.*
Arca Websteri, *Forbes.*
Nucula sphenoides, *Edw.*
Lutetia trigonula, *Edw.*
Lucina Thierensi, *Héb.*
Cardium hempsteadianum, *Edw.* MS.
—— nanum, *Edw.* MS.
—— Etheridgii, *Edw.* MS.
Cytherea Lyelli, *Forbes.*
Venus vectensis, *Edw.* MS.
—— Forbesii, *Edw.* MS.
Tellina Nysii, *Desh.*
—— vectensis, *Edw.*
—— hempsteadiensis, *Edw.*
—— corbuloides, *Edw.*
Mya minor, *Forbes.*
—— hempsteadiensis, *Edw.* MS.

Mya donacialis, *Edw.* MS.
Corbula vectensis, *Forbes.*
—— subpisum, *d'Orb.*
Panopæa Heberti, *Bosq.* (P. minor, *Forbes*).
Pholas, sp.

If we now turn our attention to the forms of life contained in the two groups of freshwater and estuarine strata alternating with the three marine series which we have indicated, the views at which we have arrived concerning the age and foreign equivalents of the latter are supported and strengthened. The lowest of these groups of freshwater and estuarine beds is more than 400 feet in thickness, and exhibits many indications of the prevalence from time to time of brackish-water and marine conditions. Hence there have been collected from these beds a considerable number of marine forms, in all about 100 species. Now if we examine their distribution, we arrive at some interesting results. About one half of them occur in the Brockenhurst series above, one third in the Barton below, while one third are peculiar, and one sixth common to all three formations.

If we compare the British with foreign deposits, we find that the marine fossils of this lower group of estuarine strata agree very closely indeed with those of the series of beds developed at many points of the Paris basin, as at Mortefontaine, Senlis, and Monneville, and now well known to geologists under the name of the "Zone of *Cerithium concavum*," Sow. ("Sous-étage de Mortefontaine" of C. Mayer).

Marine Fossils from the Brackish-water Bands of Headon Hill and Hordwell Cliffs.

[*a* Pass up into the Brockenhurst series. *x* Pass down to the Barton clay.]

a Marginella simplex, *Edw.*
—— vittata, *Edw.*
a Pleurotoma headonensis, *Edw.*
a —— denticulata, *Bast.*, var. odontella, *Edw.*
—— Woodi, *Edw.*
a, x Borsonia sulcata, *Rouault.*
a, x Rimella rimosa, *Sol.*
a, x Hippocrenes (Rostellaria) ampla, *Sow.*
a Murex sexdentatus, *Sow.*
Fasciolaria crebrilinea, *Edw.* MS.
Pisania (Fusus) scalaroides, *Lam.*
a Natica grossiuscula, *Edw.*, MS.
—— Studeri, *Bronn*, var. clausa, *Edw.*
a, x —— labellata, *Lam.*
x Odostomia hordeola, *Lam.*
a —— loxodonta, *Edw.* MS.
a —— subumbilicata, *Edw.* MS.
a —— geminata, *Edw.* MS.
a —— multispirata, *Edw.* MS.
a —— gracilis, *Edw.* MS.
x Turbonilla obliquecostata, *Edw.* MS.
—— sorella, *Edw.* MS.
a Scalaria lævis, *Morr.*
Cerithium concavum, *Sow.*
—— gyrostoma, *Edw.*

a Cerithium duplex, *Sow.*
—— ventricosum, *Sow.*
—— contiguum, *Desh.?*
—— multispiratum, *Desh.*
—— parvulum, *Edw.* MS.
—— cavatum, *Edw.* MS.
—— speculatum, *Edw.* MS.
Cæcum Morrisii, *Edw.* MS.
Lacuna clausa, *Edw.* MS.
Rissoa carinata, *Edw.* MS.
a —— ——, var. denticulata, *Edw.* MS.
—— ditropis, *Edw.* MS.
Hydrobia polita, *Edw.* MS.
a, x —— anceps, *S. Wood.*
—— Dubinsoni, *Bouillot*, var. rimata, *Edw.*
—— subangulata, *Edw.* MS.
a, x Nematura parvula, *Desh.*
—— lubricella, *A. Braun.*
Trochus pictus, *Edw.* MS.
Adeorbis æstuarina, *Edw.* MS.
—— aperta, *Edw.* MS.
a Nerita aperta, *Sow.*
a —— æstuarina, *Edw.* MS.
a Neritina concava, *Sow.*
—— neritopsidea, *Edw.* MS.
a Actæon limneiformis, *Sandb.*
Ringicula ringens, *Lam.*
a Bulla æstuarina, *Edw.* MS.
a —— Lamarckii, *Desh.*
—— tenuicula, *Edw.* MS.
x Anomia tenuistriata, *Desh.*
a Ostrea velata, *S. Wood.*
a Avicula media, *Sow.*
a Dreissena unguiculus, *Sandb.*
a, x Mytilus affinis, *Sow.*
a, x —— strigillatus, *S. Wood.*
x Modiola elegans, *Sow.*
—— ——, var. elegantior, *S. Wood.*
a Arca lævigata, *Caill.*
a, x Trigonocœlia deltoidea, *Lam.*
a Nucula headonensis, *Forbes.*
—— tumescens, *Edw.* MS.
—— ampla, *Edw.* MS.
x —— lissa, *Edw.* MS.
a —— nudata, *S. Wood.*
a Cardita oblonga, *Sow.*, var. transversa, *Edw.* MS.
—— ——, var. serratina, *Edw.* MS.
x Lucina inflata, *Edw.* MS.
a, x —— obesa, *Edw.* MS.
x —— concava, *Defr.*
a —— pulvinata, *Edw.* MS.
x —— gibbosula, *Lam.*
—— pratensis, *Edw.* MS.
a Strigilla colvellensis, *Edw.* MS.
—— pulchella, *Agass.*
a, x Cardium obliquum, *Lam.*
a, x Scintilla angusta, *S. Wood.*
—— nitidulum, *S. Wood.*
a, x Cytherea incrassata, *Sow.*
—— partimsulcata, *Edw.* MS.
a —— suborbicularis, *Edw.* MS.

a Psammobia æstuarina, *Edw.* MS.
a, x —— rudis, *Lam.* (P. solida, *Sow.*).
x Tellina ambigua, *Sow.*
—— reflexa, *Edw.*
a, x Mya angustata, *Sow.*
a —— producta, *Edw.* MS.
a Corbula nitida, *Sow.*
a —— cuspidata, *Sow.*
a, x —— pisum, *Sow.*
—— fortisulcata, *Edw.* MS.
a, x Panopæa subeffusa, *Edw.* MS.

The comparison of the terrestrial and freshwater Mollusca of these two groups with one another, and with the forms contained in strata of equivalent age upon the Continent, is now greatly facilitated by the publication of Prof. Sandberger's "Land- und Süsswasser-Conchylien der Vorwelt." The conclusions to which we are led are in perfect agreement with those which result from the study of the marine faunas. About 120 forms of freshwater and terrestrial Mollusca have been described as occurring in these strata. Of these more than one half are peculiar to the Headon beds, about one quarter are peculiar to the Bembridge, while the remainder are common to the two groups of strata. The distribution of these forms is illustrated in the following Table:—

Freshwater and Terrestrial Mollusca of the Oligocene of the Isle of Wight.

	Bembridge group.	Headon group.
Helix globosa, *Sow.*	*	
—— Morrisii, *Edw.*	*	
—— tropifera, *Edw.*	...	*
Fruticola (Helix) vectensis, *Edw.*	*	*
Hyalina (Helix) d'Urbani, *Edw.*	*	*
Nanina (Helix) occlusa, *Edw.*	*	*
Patula (Helix) omphalus, *Edw.*	*	*
Strobilus (Helix) sublabyrinthicus, *Edw.*	...	*
—— (Helix) pseudolabyrinthicus, *Sandb.* (= H. labyrinthica, *S. V. Wood*, non *Say*)	...	*
Gastrodonta (Helix) headonensis, *Edw.*	...	*
Bulimus convexus, *Edw.*	*	
Glandina (Bulimus) costellata, *Sow.*	*	
Amphidromus (Bulimus) ellipticus, *Sow.*	*	
Nystia (Bulimus) polita, *Edw.*	...	*
Pomatias (Bulimus) heterostomus, *Edw.*	*	*
—— (Bulimus?) vectiensis, *Edw.*	*	
Cyclostoma (Pomatias) lamellosum, *Edw.*	...	*
Pupa oryza, *Edw.*	...	*
Torquilla (Pupa) perdentata, *Edw.*	*	
Clausilia striatula, *Edw.*	*	
Magalomastoma (Cyclostoma) mumia, *Lam.*	*	
Callia? (Pupina?) lævis, *Edw.*	*	
Cyclotus cinctus, *Edw.*	*	
—— (?) nudus, *Edw.*	*	

Freshwater and Terrestrial Mollusca (continued).

	Bembridge group.	Headon group.
Assiminea conica, *C. Prévost*	...	*
Succinea sparnacensis, *Desh.*	...	*
Tapada (Succinea) imperspicua, *S. Wood*	...	*
Limnæa longiscata, *Brong.*	*	*
—— ——, var.	*	
—— fusiformis, *Sow.*	*	*
—— pyramidalis, *Desh.*	...	*
—— columellaris, *Sow.*	...	*
—— fabulum, *Brong.*	...	*
—— ovum ?, *Brong.*	...	*
—— arenularia, *Brard*	...	*
—— elongata, *Marcel de Serres*	...	*
—— minima, *Sow.*	...	*
—— caudata, *Edw.*	...	*
—— sulcata, *Edw.*	...	*
—— gibbosula, *Edw.*	...	*
—— mixta, *Edw.*	...	*
—— tumida, *Edw.*	...	*
—— convexa, *Edw.*	...	*
—— subquadrata, *Edw.*	...	*
—— costellata, *Edw.*	...	*
—— cincta, *Edw.*	...	*
—— angusta, *Edw.*	...	*
—— recta, *Edw.*	...	*
—— tenuis, *Edw.*	...	*
—— sublata, *Edw.*	...	*
Ancylus (?) latus, *Edw.*	*	
Velletia elegans, *Sow.*	...	*
Nematura (?) pupa, *Nyst*	...	*
—— parvula, *Desh.*	*	*
Planorbis discus, *Edw.*	*	
—— Sowerbyi, *Brong.*	*	
—— rotundatus, *Brard*	*	*
—— obtusus, *Sow.*	*	*
—— platystoma, *S. Wood*	*	*
—— lens, *Brong.*	...	*
—— tropis, *Edw.*	...	*
—— hemistoma, *Sow.*	...	*
—— elegans, *Edw.* (P. Baudoni ?, *Desh.*)	...	*
—— biangularis ?, *Edw.*	...	*
Menetus (Planorbis) euomphalus, *Sow.*	...	*
—— (Planorbis) goniobasis, *Sandb.*	*	*
Helisoma (Planorbis) oligyratum, *Sow.*	*	
Paludina (Bythinia) globuloides, *E. Forbes*	*	
—— lenta, *Sow.*	*	*
—— concinna, *Sow.*	*	*
—— orbicularis, *Sow.*	*	*
—— lenta, var.	*	
—— minuta, *Sow.*	*	
—— angulosa, *Sow.*	...	*
Mitrula (Neritina) aperta, *Sow.*	*	*
Neritina concava, *Sow.*	*	*
—— tristis, *Forbes*	*	

Freshwater and Terrestrial Mollusca (continued).

	Bembridge group.	Headon group.
Neritina Forbesii, *S. Wood*	...	*
—— zonula, *S. Wood*	...	*
—— planulata, *Edw.*	...	*
Euchilus Chastelii, *Nyst*, sp.	*	
Potamaclis (Melania) turritissima, *Forbes*	*	*
Melania muricata, *Sow.*	*	*
—— fasciata, *Sow.*	*	*
—— costata, *Sow.*	*	*
—— Nystii, *Duchastel*	*	
—— angulata	...	*
—— conica	...	*
—— polygyra	...	*
—— minima, *Sow.*	...	*
—— interrupta, *Edw.*	*	
—— inflata, *Morr.*	*	
—— Forbesii, *Morr.*	*	
—— excavata, *Morr.*	*	
Melanopsis subulata, *Sow.*	*	
—— subfusiformis, *Morr.*	*	*
—— fusiformis, *Sow.*	*	*
—— ancillaroides, *Desh.*	...	*
—— subcarinata, *Morr.*	...	*
—— subulata, *Sow.*	...	*
Hemisimus (Melanopsis) brevis, *Sow.*	*	*
Macrospina (Melanopsis) carinata, *Sow.*	*	*
Unio Austenii, *Forbes & Morr.*	*	
—— Gibbsii, *Forbes & Morr.*	*	
—— Solandri, *Sow.*	...	*
—— tumescens, *Edw.* MS.	...	*
—— vectensis, *Edw.* MS.	...	*
Corbicula (Cyrena) obovata, *Sow.*	*	*
Batissa (Cyrena) obtusa, *Forbes*	*	
Cyrena semistriata, *Desh.*	*	
—— pulchra, *Sow.*	*	
—— transversa, *Forbes*	*	
—— britannica, *Desh.*	...	*
—— pisum, *Desh.*	...	*
—— cycladiformis, *Desh.*	...	*
—— pulchra, *Sow.*, var. Wrightii, *Forbes*	...	*
—— arenaria, *S. Wood*	...	*
—— tenera, *S. Wood*	...	*
—— gibbosula, *Morr.*	...	*
Cyclas Bristovii, *Forbes*	*	
—— tumidula, *S. Wood*	...	*
Sphenia angustata, *Sow.*	...	*
—— minor, *Forbes*	*	
Potamomya plana, *Sow.*	*	*
—— gregaria, *Sow.*	...	*
—— angulata, *Sow.*	...	*

The freshwater and terrestrial Mollusca of the strata above the Brockenhurst series in many cases belong to species which occur likewise in the Calcaire de St. Ouen and the gypseous series of Montmartre in the Paris basin, in the Palæotherium-Limestone of the South of France, and in strata of the same age in Belgium and Northern Germany. The forms which occur in the beds below the Brockenhurst series are many of them common to the Tongrian of Belgium and the Lower Oligocene of Northern Germany.

A very considerable number of vertebrate forms has been obtained from this great estuarine series of beds. Teeth of *Squalus* and *Myliobates*, and scales and teeth of *Lepidosteus*, abound in the lower group. Of reptiles we have the remarkable *Crocodilus Hastingsiæ*, Owen (of which the fine *Alligator hantoniensis* of S. Wood is believed by both Owen and Huxley to be only a variety). With this Crocodilian we have also in the lower series of estuarine strata a number of remarkable Chelonians, including *Trionyx Henrici*, Owen, *T. Barbaræ*, Owen, *T. marginatus*, Owen, *T. rivosus*, Owen, *T. planus*, Owen, *T. circumsulcatus*, Owen, with *Emys crassa*, Owen, and *E. hordwellensis*, Seeley. There have also been found at the same horizon some Ophidian and Lacertilian remains that as yet remain undescribed. In the Upper series of estuarine beds lying above the Brockenhurst series, the only recorded reptilian form is the *Trionyx incrassatus*, Owen.

The study of the Mammalian fauna of these beds yields some facts of considerable interest. The beds above the Brockenhurst series have yielded four species of *Palæotherium*, two of *Anoplotherium*, one of *Chœropotamus*, two of *Hyopotamus*, and one of *Dichobune*. The beds below the Brockenhurst series have yielded three species of *Palæotherium*, all distinct from those of the beds above, with representatives of the genera *Palaplotherium*, *Dichobune*, *Microchœrus*, *Spalacodon*, *Hyænodon*, and *Dichodon*. There also exist in the British and Woodwardian Museums, and in some private collections, undescribed vertebrate remains, which, when carefully studied, will probably throw much new light on the terrestrial life of this period.

In 1862 Prof. Heer described the following ten species of plants as derived from the black band of Hamstead in the upper of the two estuarine series. These are *Sequoia Couttsiæ*, Heer, *Cyperites Forbesi*, Heer, *Sabal major*, Ung., *Andromeda reticulata*, Ett., *Nymphæa Doris*, Heer, *Nelumbium Buchii*, Ett., *Carpolites Websteri*, Brong., *Carpolites globulus*, Heer, *Chara Escheri*, A. Brong., and *Chara tuberculata*, Lyell, var. Of these no less than six, as pointed out by Prof. Heer, are well-known species, found in Switzerland and elsewhere in the Aquitanian and Tongrian divisions of the Tertiary series, or in strata which are now classed with the Oligocene.

In the lower series of estuarine strata, or Headon group, Gyrogonites are the only common plant-remains. One of the forms, *Chara Wrightii*, Forbes, is peculiar to the Headon group; and another, *C. tuberculata*, Lyell, is common to both the Bembridge and Headon groups. Mr. J. Starkie Gardner records a feather-palm from these beds*.

* Monograph of the British Eocene Flora, Pal. Soc. 1879, p. 20.

VI. Subdivisions and Nomenclature of the Series.

According to the classification of the Tertiary strata usually followed in this country, it is necessary to divide the fluvio-marine series into two portions, placing one in the Eocene and the other in the Miocene. This is the grouping of the strata followed by the late Sir Charles Lyell; and no one who has studied the faunas of the Hempstead beds, and of their equivalents the Fontainebleau Sandstone of the Paris basin, and the Rupelian of Belgium, can for one moment doubt that this classification is well founded. The fauna of the Fontainebleau Sandstone and of the Rupelian being unquestionably more closely related to the Miocene than to the Eocene, it is quite impossible to accept the grouping adopted by the Geological Survey, and followed in most English text-books of geology, and to extend the Eocene or Nummulitic series upwards so as to embrace beds containing such faunas as those of the Brockenhurst and Hempstead series.

On the other hand the inconvenience of breaking up so natural a group of strata as that which the fluvio-marine beds of the Hampshire basin manifestly constitute is apparent to every one; and it is doubtless this conviction which has operated in preventing the general acceptance of the Lyellian classification. It has been felt, and rightly too, that no such break in continuity exists between the Hempstead and Bembridge strata as would warrant their being placed in distinct divisions of the geological series.

Fortunately a method of classification is open to us which, while it does not break up this natural group of the Fluvio-marine of the Hampshire basin, yet enables us to refer its members to divisions of the geological series which have been based on the careful and exact study of the faunas of the Tertiary strata all over Europe. This classification completely satisfies the apparently opposing requirements of the physical geologist and the palæontologist.

In the year 1854 Prof. Beyrich, in describing the nature and affinities of the fauna which was yielded by the Tertiary beds of Northern Germany, pointed out that the same difficulty is found in defining whether they should be regarded as Eocene or Miocene as is the case with the English strata which we are now considering. He further showed how recent discoveries had added greatly to the importance which must be attached to the beds on this horizon, beds which he has demonstrated to be represented by deposits of great thickness, not only in Hampshire but in the Paris basin, Belgium, the Mayence basin, and Northern Germany; and he suggested that these strata form a division of such consequence, and containing a fauna so distinct, that they deserve to be erected into a new grand division of the Tertiary series. For this division of the geological series Prof. Beyrich proposed the name of "Oligocene," a term formed on the same principle as was adopted by Lyell in devising names for the other divisions of the Tertiary strata.

This division of the Tertiary series, to which Beyrich applied the name of Oligocene, has now come to be very generally recognized on the Continent. It has been shown that, not only in the districts in which its existence was first made known, but also in Switzerland, Italy, and Hungary, deposits are found, sometimes attaining a thickness of several thousands of feet, which contain the same well-characterized fauna, and must be referred to the same division of the geological series. And by the labours of Beyrich, Von Könen, Sandberger, Mayer, Von Hantken, and many other palæontologists our knowledge of the extent and peculiarities of the fauna has been greatly enlarged.

The marine fauna of the Hempstead beds unquestionably agrees in the closest manner with that of the Fontainebleau Sandstone, the Rupelian of Belgium, the marine sand of the Mayence basin, and the clays of Hermsdorf, Cassel, &c. in Northern Germany. All of these strata are now recognized as belonging to the Middle Oligocene.

The Brockenhurst beds contain a rich fauna, the analogues of which, as we have seen, are not found in the Paris basin (where the strata of this horizon are of freshwater origin), but which find their exact representatives in the Lower Tongrian of Belgium and the Clays of Lattorf, Egeln, and Helmstadt in Northern Germany. These constitute the Lower division of the Oligocene.

With regard to the beds which underlie the Brockenhurst series, those, namely, of Headon Hill and Hordwell Cliff, there is equally little room for doubt. They unquestionably represent the "Zone of *Cerithium concavum*," which was long ago recognized as existing in the Paris basin by Prof. Hébert, and of which the importance has been more recently demonstrated by Dr. C. Mayer and Prof. Sandberger. On one point some little difference of opinion may still exist—namely, as to whether the strata of the Zone of *Cerithium concavum* should be placed in the Eocene or Oligocene. As we have already pointed out, a study of the marine forms which they contain proves that the fauna is intermediate between those of the Barton and Brockenhurst series. Both Dr. Mayer and Prof. Sandberger incline to the view that they should be grouped with the Bartonian, and regarded as an upper member of that division. In this country, on the other hand, as also in the Paris basin, the evidence appears to me to point in the other direction, and I cannot but regard this Zone of *Cerithium concavum* as the base of the Oligocene—a view which is shared by Prof. Beyrich himself. As a matter of fact, the fauna of the beds in question is so strictly intermediate in character between the Barton and the Brockenhurst faunas, that it may be regarded as a question of convenience whether they should be grouped with one or the other. In this country there can be no doubt that convenience demands that they should be grouped with the other fluvio-marine beds.

In dealing with the classification of the Oligocene strata of the Hampshire basin it is desirable to retain as far as possible the local groupings which are already familiar to geologists, only making such corrections as the new facts discovered concerning the succession of the strata prove to be absolutely indispensable.

Table of the Oligocene Strata of Western Europe.

	Hampshire basin.	Paris basin.	Netherlands.	North Germany and Mayence basin.	Switzerland.
Upper Oligocene.	Absent.	Freshwater limestone of Beauce. Millstones of Montmorency &c.	Beds of Maestricht.	Strata of Osnabruck, Bünde, Cassel, Wiepke, &c. Lower Rhenish Brown Coal. Cyrena Marl of the Mayence basin.	Brown Coal formation (Aquitanian).
Middle Oligocene.	Hempstead series. Bembridge group.	Upper Fontainebleau Sandstone. Lower Fontainebleau Sandstone. Green Marls of Montmartre. Millstones and Marls of Brie.	Rupélien. Tongrien supérieur.	Septarian Clay. Marine Sand of the Mayence basin.	Lower Marine Molasse (Tongrian).
Lower Oligocene.	Brockenhurst series. Headon group.	Gypsum of Montmartre. Marine Marls. *Cerithium-concavum* beds of Mortefontaine &c. Freshwater Limestone of St. Ouen.	Tongrien inférieur.	Clay of Egeln, and shell-beds overlying the Brown Coal.	Upper Flysch and top of Nummulitic series.
Upper Eocene.	Barton Clay.	Sands of Beauchamp.	Laekénien.	Brown Coal.	Nummulitic.

First in importance we have the strata containing the three marine faunas, which, as we have seen, are so well characterized and are so distinct from one another. The name of Bartonian is now accepted everywhere for the strata containing the *first* and lowest marine fauna and their continental equivalents. For the beds which contain the *second* marine fauna, I have proposed the name of the *Brockenhurst series.*

For the beds containing the *third* and highest marine fauna, I propose to retain the name of the Hempstead series. It is a very unfortunate circumstance that, in selecting this name, Prof. Edward Forbes was labouring under a mistake. As I have already pointed out, Hamstead, in the Isle of Wight, is spelt in a different manner from that of the well-known London suburb; while the name of Hempstead is not only quite unknown in the Isle of Wight, but belongs to localities in Essex and Hertfordshire. Nevertheless the inconvenience of changing a name which has been so generally adopted both in this country and abroad is so manifest that I do not propose to interfere with it. It is desirable, however, to restrict its application to the more purely *marine* strata constituting the upper 100 feet of the section in the Isle of Wight. The grounds on which Prof. Forbes separated the estuarine marls below the marine strata of Hamstead from the Bembridge marls below can now be shown to be very unsubstantial. The occurrence of a lignite seam like the "Black band" of the Hempstead series is too common a circumstance in the case of these fluvio-marine beds to warrant us in making it the limit between two series of strata; while the first appearance of *Hydrobia* (or *Rissoa*) *Chastelii*, to which Prof. Forbes attaches so much importance, loses its significance now that, as is shown by Prof. Sandberger, the shell in question is recognized as a freshwater form belonging to the genus *Euchilus.*

In dealing with the estuarine strata which separate these three marine groups, the Barton, the Brockenhurst and the Hempstead, I am impressed with the desirability of avoiding the multiplication of names for small and local groups of these strata, where no good palæontological grounds can be shown for such divisions. The strata are so inconstant in their mineral characters, and it is so manifestly impossible to trace them at the surface by the methods at the command of the geological surveyor, that such minute subdivision of the beds can tend only to the confusion rather than to the elucidation of their relations.

I therefore propose to extend the name of the Headon series so as to cover all the beds between the Barton and the Brockenhurst series, and to call all those strata which, as we have seen, belong to the palæontological Zone of *Cerithium concavum*, the Headon group. The divisions of Upper, Middle, and Lower Headon cannot, as I shall show, be traced to any distance; and we therefore regard the abandonment of these smaller subdivisions as an actual advantage. The Headon group, as now constituted, will embrace the whole of the true Headon series, with certain others both above and below it.

To all the beds between the Brockenhurst and Hempstead series I propose to apply the name of the "Bembridge group," which also includes strata both above and below the "Bembridge series" of Edward Forbes. It includes not only the Bembridge limestone and marls of that author, but also beds referred by him to the base of the Hempstead, the Osborne and St. Helens, and to the Upper Headon. These great changes in the classification and nomenclature of the strata are rendered absolutely necessary by the discovery that has been made of the error in the existing views of the succession of the strata.

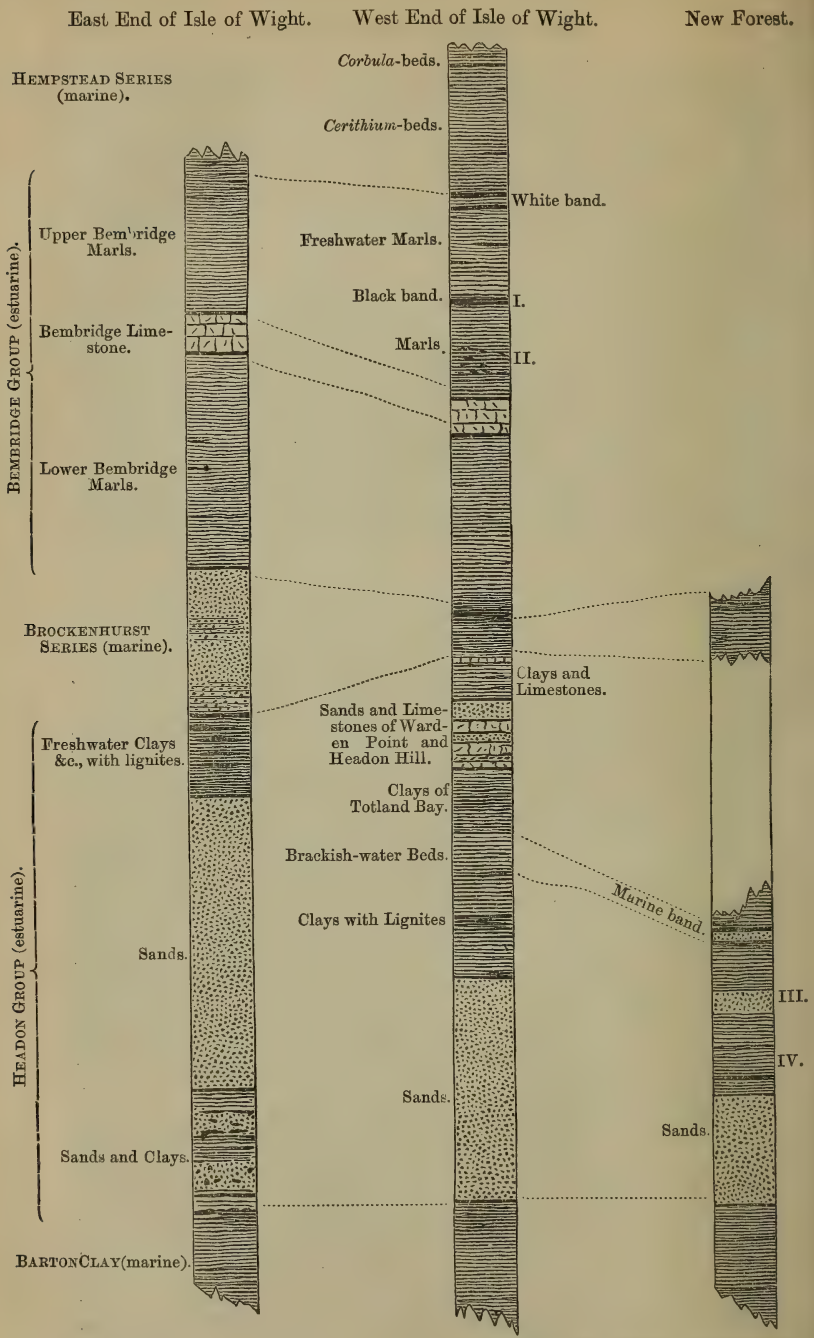
With respect to Forbes's division of the "Osborne and St. Helen's series," I think that it had better be given up altogether, and on the following grounds:—*First*, there are no good characters, either physical or palæontological, by which this division can be defined. *Secondly*, the separation of this division from those above and below it has been found so difficult, that even in the different publications of the Geological Survey very serious discrepancies exist as to the limits of the series; and *thirdly*, 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.

VII. Thickness of the Strata and their Development in different Areas.

Immediately above the richly fossiliferous Barton Clay we find a series of sandy strata with subordinate argillaceous beds. At Alum Bay these strata attain a very considerable thickness, which has been variously estimated at from 100 feet to 200 feet; it is probably not less than 150 feet. These Headon-Hill sands are usually called the Upper Bagshot beds; but it appears to me that it cannot but be a source of confusion to base our classification of the Upper Eocene strata on the poorly fossiliferous deposits of the London basin rather than on the richly fossiliferous deposits of the Hampshire basin. It is true that at Alum Bay the Headon-Hill sands have not yielded any fossils; but the equivalent beds at Hordwell Cliff contain a by no means scanty fauna, in which we find the same admixture of marine and freshwater forms which characterizes the overlying Headon strata. As, moreover, we detect in these beds the eminently characteristic fossil *Cerithium concavum*, it seems clear that we must regard them as constituting the lowest member of the Headon group.

The Headon group, as exhibited at the western extremity of the Isle of Wight, is about 400 feet in thickness. It consists in the upper part of freshwater and terrestrial beds,—beds of limestone containing *Limnœa*, *Paludina*, *Planorbis*, and other pulmoniferous Gasteropods, alternating with sands and clays containing freshwater fossils, while beds of lignite, sometimes a foot or two in thickness, indicate old terrestrial surfaces. But in all the lower part of the series we find a tendency to the recurrence of brackish-water conditions; and in these intercalated fluvio-marine bands we find numerous *Cerithia*, *Cyrenæ*, and dwarfed *Ostreæ*.

Comparative Vertical Sections of the Oligocene Strata of the Hampshire Basin.
(Scale, $\frac{3}{4}$ inch to 100 feet.)



I. Horizon of Plant-remains described by Mr. Pengelly and Prof. Heer; II. Horizon of bed containing Insect and Crustacean remains discovered by Mr. A'Court Smith; III. Horizon of bed containing Crocodilian and other Reptilian remains at Hordwell; IV. Horizon of bed with Mammalian remains at Hordwell.

When the beds of the Headon group are traced over to the opposite coast of Hampshire, they are found at Hordwell, apparently diminished in thickness; and here we have evidence of the existence of numerous reptilian and mammalian forms of life which do not occur in the Isle-of-Wight strata. Unfortunately, however, the exposure is incomplete, only the lowest 100 feet of the group being seen in the cliff section. The correspondence both of the freshwater and brackish forms of the Mollusca at Headon Hill and Hordwell is perfect, and leaves no room for doubt that the two series of strata are upon the same geological horizon.

When we pass to the eastern extremity of the Isle of Wight, we find at Whitecliff Bay a very different series of strata from that exposed at Headon Hill. Immediately below the well-marked Brockenhurst series at Whitecliff Bay we have a series of clays and lignites with some bands of ironstone, which appear to be entirely of freshwater origin. These are estimated by Mr. Prestwich at 92 feet in thickness; but the officers of the Survey make them only 40 feet. My own measurements indicate a thickness intermediate between these two amounts, namely about 60 feet. Below these we have 200 feet of sands usually identified with the Headon-Hill sands, but which I cannot but regard as representing all the lower part of the Headon group. Unfortunately they do not contain any fossils, with the exception of the casts of a few undeterminable bivalves. As is well known, the Barton series is very imperfectly represented at Whitecliff Bay, and it is difficult to draw a boundary either between the Bracklesham and the Barton beds or between the latter and the overlying fluvio-marine strata.

The Brockenhurst series is represented at Whitecliff Bay by 100 feet of purely marine strata. The identity of these with the beds of the New Forest, so well worked out by Mr. Edwards and Herr Von Könen, has already been recognized by Mr. Fisher * and by Messrs. Jenkins and Codrington †. At Colwell Bay this marine series is reduced to a thickness of 25 feet; but the number of its fossils is so great as to render its correlation with the Brockenhurst beds unquestionable. In the New Forest, unfortunately, we have no clear sections showing the thickness and succession of the Brockenhurst series. A well-section, observed by Mr. Henry Keeping and recorded by Mr. Wise in his work on the New Forest, shows that the thickness of this marine series is certainly not less than at Colwell Bay. Considering the wide area over which the fossils of this horizon have been found, the thickness of the Brockenhurst series in the New Forest is probably very considerable.

The Bembridge group consists of a series of beds which at the western end of the Isle of Wight attain a thickness of more than 250 feet. In the midst of the series occurs the well-known limestone of Bembridge, having a thickness of about 25 feet. We may distinguish the beds above and below the Bembridge Limestone respectively as the Upper and Lower Bembridge Marls. The Lower

* Quart. Journ. Geol. Soc. vol. xviii. (1862) p. 67.
† *Ibid.* vol. xxiv. (1868) p. 519.

Bembridge Marls separate the Bembridge Limestone from the Brockenhurst series, and are about 100 feet in thickness. Their fossils are entirely such as lived in fresh water. The Upper Bembridge Marls are about 130 feet in thickness (including the lower parts of the beds formerly referred to the Hempstead series), and are much more richly fossiliferous than the Lower Bembridge Marls. Near their base and at a little distance above the Bembridge Limestone occurs the band of fine-grained limestone which has yielded to Mr. A'Court Smith such a large number of crustacean and insect remains, some of which have been described by Dr. Woodward* and the Rev. P. B. Brodie†. In the higher part of the Upper Bembridge Marls there occurs a lignite bed (Black Band) which has yielded a considerable number of plant-remains‡. At the eastern extremity of the Isle of Wight the Bembridge group is nowhere exhibited in its entirety, but the thickness of strata above the Brockenhurst series is found to be 220 feet.

The Lower Bembridge Marls are here about 140 feet in thickness, and, as at the western extremity of the Isle of Wight, contain but few fossils, and these entirely of freshwater species. But at one point at the east end of the Isle of Wight (namely, between Ryde and St. Helens) these lower beds of the Bembridge group assume a totally distinct character, and are seen as strata of sand and sandstone, occasionally passing into conglomerates. To the upper part of this arenaceous representative of the Lower Bembridge Marls, Prof. Forbes gave the name of the "St. Helen's Sands;" and the lower part he called the "Nettlestone Grits." The Bembridge Limestone is very constant in character and thickness wherever it is seen in the Isle of Wight. The Upper Bembridge Marls at the eastern part of the Isle of Wight are generally similar to the beds on the same horizon at the west end of the island; but about 5 feet above the top of the Bembridge Limestone there occurs a band containing *Ostreæ*, *Cytherea incrassata,* and other marine forms mingled with freshwater shells. This band was long confounded with the "Venus-beds" of Colwell Bay and Headon Hill, its distinctness from these being first established by Prof. Edward Forbes. Only about 80 feet of the lower part of the Upper Bembridge Marls are exposed at the east end of the Isle of Wight.

Although the Bembridge Limestone is found at Sconce, stretching beneath the sea in the direction of the Hurst-Castle promontory, and isolated exposures of Bembridge beds are seen in Hampshire, yet no continuous sections of the Bembridge group are found in the New-Forest area.

The Hempstead series is only clearly exposed at the Hamstead and Bouldnor Cliffs; but, as pointed out by Mr. Godwin-Austen, there are proofs of the existence of these beds on the high ground covered by Parkhurst Forest§, while Dr. Wilkins has found them

* Quart. Journ. Geol. Soc. vol. xxxv. p. 343.
† Proc. Warwickshire Nat. & Archæol. Field-Club, 1878.
‡ Quart. Journ. Geol. Soc. vol. xviii. p. 369.
§ 'On the Tertiary Fluvio-marine Formation of the Isle of Wight' (1856), p. 37.

on the Osborne estate on the east side of the Medina*. It is not improbable that under the extensive beds of gravel that almost everywhere conceal the Oligocene strata in the northern part of the Isle of Wight, the Hempstead beds may be present at many points. They have not, however, been detected on the north side of the Solent.

The portion of the Hempstead series, as now limited by me, which is exposed at Hamstead Cliff, is about 100 feet in thickness. The incoming of brackish-water conditions at the base of the series is marked by the appearance of numerous forms of *Cerithium* and marine Mollusca. At the top of the series the marine forms become much more numerous. The Hempstead beds represent, as we have pointed out, the lower part of the Middle Oligocene; whether the representatives of the remainder of the Middle Oligocene and of the Upper Oligocene were ever deposited in the Hampshire basin we have unfortunately no means of determining. It is interesting, however, to notice that the Lower Oligocene and the inferior portion of the Middle Oligocene deposits are in this country more than 900 feet in thickness.

VIII. Conclusion.

Whether we regard the enormous thickness of the beds deposited during this portion of the Tertiary epoch, the marked and distinctive characters of both the marine and terrestrial faunas, or the vast changes in the distribution of land and water, of which we have such clear proofs in the deposits of this period, it must be admitted that the Oligocene is worthy to rank among the great divisions of the Cainozoic epoch, and must be regarded as of equal value with the Eocene, the Miocene, or the Pliocene.

It is clear that at the commencement of the Oligocene period great changes must have taken place in the physical geography of Europe and Asia. Large areas, in which marine deposits had been slowly accumulating during the Nummulitic period, were now upheaved and formed dry land; and though the sea from time to time re-invaded these areas, the deposits formed in Europe during the Oligocene period were to a great extent of terrestrial and lacustrine origin, while the marine strata were, for the most part, quite subordinate to these. During Eocene times marine conditions, due to continued subsidence, prevailed; and during Miocene times terrestrial conditions, resulting from elevation, existed: the Oligocene was deposited in a period of oscillation (one of enormous duration) which separated these two epochs.

The reason why the importance of the marine fauna representing the Oligocene was so long overlooked, is to be sought for in the circumstance that marine strata of this age are usually thin and subordinate to intercalated freshwater or estuarine beds; and the fact that the strata of this age are very frequently covered by thick superficial accumulations long prevented the collection and study of the fossils of the period.

It was during the Oligocene period that those great movements commenced which resulted in that folding and crumpling of strata,

* Proc. Geol. Assoc. vol. i. p. 194.

so strikingly exhibited in the Alps and Himalayas and the other great ranges which constitute the axis of the eastern continent. At the same time, too, began those volcanic outbursts along lines parallel to this axis, which attained their climax in the Miocene period, and have not yet died out at the present day.

The Oligocene was a period at which, as we have seen, many oscillations in the level of the land and sea took place in this part of the globe, elevation and subsidence alternating with one another again and again. Hence we find the thickness of the several deposits exhibiting great variations within very short distances. In eastern Europe (Hungary and Transylvania) the Oligocene strata attain a thickness of from 2000 to 3000 feet, and contain numerous beds of coal, one of which, in the Tsilthal, measures no less than 90 feet. But in Northern and Western Europe the Oligocene is represented by a series of delta deposits of much less considerable thickness. As, however, we approach the great mountain axis, where the maximum amount of movement has taken place, we find that deposits of enormous thickness have been accumulated, as in Bavaria, Switzerland, and Northern Italy, where beds of this age attain a thickness of from 10,000 to 12,000 feet.

That the Oligocene must represent a period of enormous duration we cannot, after what has been stated concerning the thickness of the deposits, for one moment doubt. And this conclusion is fully sustained when we come to study the marine and terrestrial forms of life which flourished while these strata were being accumulated. The labours of Beyrich, Von Könen, Sandberger, and others have now made known to us a marine fauna consisting of several thousands of species; and this fauna is found to be clearly distinguished alike from that of the Eocene below and that of the Miocene above. The reasons why Lyell failed to recognize this great fauna and to include it in his scheme of classification of the Tertiary strata, we have already pointed out. The terrestrial fauna and flora of the Oligocene is also as distinct from those of the Eocene and Miocene respectively, as is the marine fauna; and the characteristic Oligocene terrestrial fauna and flora have been recognized, not only in the Eastern continent, but in North America.

That which has been asserted of the Oligocene formation generally, may be maintained with equal truth concerning its representatives in these islands, the fluvio-marine strata of the Hampshire basin. These strata, although they unfortunately furnish only a fragmentary record of the earlier portions of the Oligocene period, are nevertheless between 800 and 900 feet in thickness. They contain a marine fauna and a terrestrial fauna and flora agreeing in the most perfect manner with those of the continental Oligocene; and, moreover, the great zones of life determined in the latter can, as we have pointed out, be clearly recognized in the former. Like the continental Oligocene strata, our fluvio-marine beds were evidently deposited during a period of oscillation which followed the long-continued submergence of the Eocene or Nummulitic, and preceded the final and most violent of those movements to which the plication and metamorphism of the Alpine rocks bear such striking testimony, movements which brought about those terrestrial conditions that prevailed over so large an area in Miocene times. Of these great movements we are not without illustrations in this country; for striking evidences of them are afforded in the folded, uptilted, and occasionally inverted strata of the Hampshire basin.

When it is further remembered that the classification of the fluvio-marine strata in our Hampshire basin has always presented peculiar difficulties to geologists, and that for a long time no course seemed open to them between unnaturally extending the bounds of the Eocene so as to embrace them, or else of breaking up this homogeneous mass of deposits and placing one part in the Eocene and the other part in the Miocene, I think we may assert of any method which avoids both of these inconvenient arrangements that it is worthy of the most serious attention; and if I have not been altogether unsuccessful in the manner in which I have presented the subject, the exact agreement of our Hampshire fluvio-marine strata with the lower divisions of the continental Oligocene must be clearly apparent to everyone.

It is of course a matter of comparative indifference to geologists whether they classify the Cainozoic deposits in three or four great groups; but I maintain that the thickness of the strata and the distinctness of the fauna and flora of the Oligocene are such as to entitle it to take rank as a great system by itself, and that this is a more natural arrangement than to group it either with the Eocene or Miocene, or to divide it between those two systems of strata.

It is no answer to this argument to assert that beds are found forming a complete transition from the Eocene to the Oligocene, and others which bridge over the gap between the latter and the Miocene. As our acquaintance with the geological series grows over widening areas, such transition deposits will constantly be discovered. Few will be bold enough to assert that because we find in the Vienna basin a continuous series through the Miocene into the Pliocene, therefore these two great divisions ought to be given up: for on such grounds every possible classification and terminology of geological deposits would have to be abandoned. I argue for the use of the term Oligocene in this country because its convenience has been felt and demonstrated over a large part of the continent, and because it enables us to get rid of serious difficulties connected with the classification of a very important part of our British series of strata.

EXPLANATION OF PLATE VII.

In fig. 1 is given a *facsimile* of the diagram published in Forbes's 'Tertiary Fluvio-marine Formation of the Isle of Wight,' p. 89. In this section no attempt has been made to maintain the relative proportions between the heights of the several cliffs; and hence several serious errors are committed in joining the different strata by means of dotted lines. The Headon-Hill sands are represented as occupying not only the whole base of Headon Hill itself, but as being largely developed in Totland Bay. Yet a careful examination of the section will show that this view is quite erroneous. As the Headon-Hill sands are 70 feet beneath the marine band (Middle Headon), we ought, if Forbes's view of the identity of the Colwell-Bay and the Headon-Hill marine beds be the correct one, to find them in Totland Bay; for there are 120 feet of strata between the Colwell-Bay marine band and the shore at Totland Bay. Hence Forbes was fully justified, taking his interpretation of the section, in placing the Headon-Hill sands where he did; and the fact of their absence at this point is clear proof that he was mistaken in his interpretation.

In fig. 2 the vertical and horizontal scales are different, but the relations between the several heights, as fixed by the new Ordnance Survey maps, are carefully maintained. Now the position of the Bembridge Limestone on Headon Hill is found to be 250 feet above the sea-level, at the point where the brackish-water strata of Headon Hill crop out on the shore. The vertical sections of the Geological Survey give the distance between the Bembridge Limestone and the Headon-Hill brackish-water bed as 125 feet. The discrepancy is so great that it is impossible to account for it by supposing a sudden thickening and change in character of the whole of the beds. But the new interpretation, illustrated by the dotted lines in this figure, removes all difficulties, and the strata of Headon Hill are brought into exact correlation with those of Totland Bay. Unfortunately that part of the section in which the Brockenhurst series would be found is entirely concealed by a talus from the beds above and the gravel which caps the hill.

In fig. 3 the same section is drawn upon the same vertical and horizontal scale, so that the exact relations of the several beds are clearly shown.

Discussion.

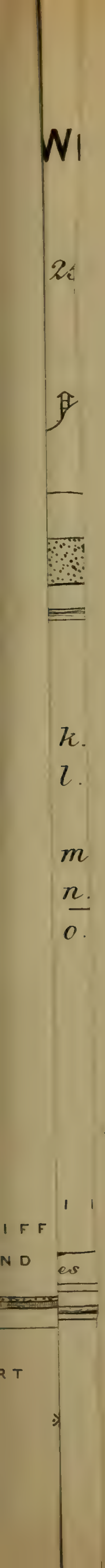
The President, in proposing a vote of thanks, expressed his sense of the value of Prof. Judd's communication.

Prof. Prestwich said that, notwithstanding the ability displayed in the paper, he was not yet prepared to accept all the conclusions, more especially as regards the correlation of the Headon-Hill beds. It was his impression that the Headon-Hill sands just reappeared in Totland Bay, and that the variation noticed by Prof. Judd in the marine beds at Headon Hill and Colwell Bay might be due to the more freshwater conditions which prevailed at the former place. He doubted also if the beds at Brockenhurst quite bore out Prof. Judd's opinion. It must be remembered that these beds varied much in thickness and in character. As to the importance of the Oligocene formation, he quite agreed with the author.

Prof. Duncan referred to the contests on the subject of the term Oligocene in the year 1863. He had studied the classification of these beds from the point of view of their coral fauna. That showed the existence of a formation intermediate between Eocene and Miocene. Beds in Scinde bore similar testimony to those of Europe.. This was represented in Britain by the Brockenhurst fauna, which he had considered the equivalent of the "Tongrien Inférieur." He welcomed therefore Prof. Judd's classification and acceptance of the Oligocene.

Mr. Etheridge said Von Könen had identified the Oligocene in England in 1863. He thought Prof. Judd had gone far to clear up the difficulty which every student must have felt about the Colwell-Bay beds. After reading the details given by Prof. Judd in his paper, it might be possible to form an opinion as to the reason of the remarkable oscillations shown in the south of England and in Germany by this series. To clear up some of these difficulties would be a great boon to the Tertiary geologist.

Prof. Seeley thought that Von Könen had identified the Colwell-Bay bed with the Brockenhurst [Prof. Judd explained it was so; but he had identified them with the Headon-Hill beds also]. There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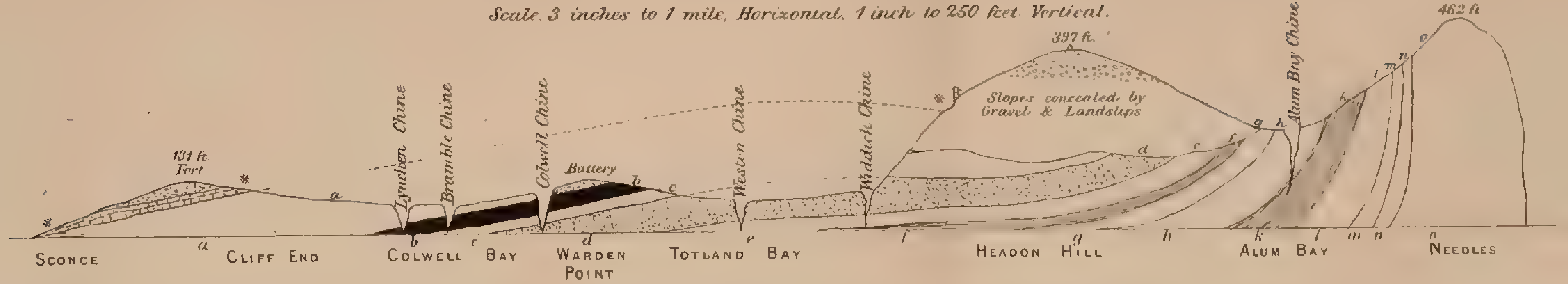
Section of strata exposed between Sconce Point and the Needles. I. of Wight.

Fig. 1. Old Interpretation (after Edward Forbes.)

1. Plastic clay
2. London clay
3. Lower Bagshot
4. Middle Bagshot
5. Sands at base of Headon Hill
6. Lower Headon
7. Middle Headon or marine beds
8. Upper Headon
9. Osborne or St Helen's beds
10. Sconce or Bembridge limestone

Fig. 2. New Interpretation

Scale. 3 inches to 1 mile, Horizontal. 1 inch to 250 feet Vertical.



× Bembridge Limestone	25 ft	Bembridge Group	
a Lower Bembridge Marls	130 ft		
b Brockenhurst Series	25 ft		
c Clays & Limestone	30	Headon Group	
d Sandstones & Limestones	50		
e Clays, lignites & ironstones	10		
f. Brackish-water beds	30		
g. Clays & lignites	70		
h. Headon-Hill Sands	150?		
k Barton & Bracklesham Series		Eocene	
l Estuarine Sands (Bagshot & Bournemouth Beds)			
m. Bognor Series			
n Plastic Clay			
o. Chalk			

Fig. 3. Section drawn to true Scale 1 inch to 240 yards.

× Bembridge Limestone αα Marine beds of the Brockenhurst Series ββ Fluvio marine beds of the Headon Group (Note these two beds have hitherto been confounded with one another)

Danielfield Lith 22 Bedford St Covent Garden

was certainly some parallelism between the Middle Headon and the Brockenhurst, though less than between the Colwell-Bay beds and the Brockenhurst. He had therefore thought the marine series might be one whole group representing the Brockenhurst. He inquired where Prof. Judd proposed to class the Upper-Bagshot sands. He asked what number of fossils were common to the above beds. He objected to the classification of the Tertiary strata into Miocene, Oligocene, Eocene, &c., as laying down laws before the evidence for them was in existence, and thought it was better, seeing that the fossils changed with the localities, to give local names to the formations.

Mr. Tawney stated Mr. H. Keeping's objections to the identification of the Colwell and Headon beds. He explained the greater number of species in Colwell Bay by the imperfection of the collection from Headon Hill.

Rev. J. F. Blake thought that the assemblage of fossils seen in the field was more important than the regarding of rare fossils; adding that he thought the Colwell-Bay bed was distinct from the Headon-Hill bed.

Mr. Gardner said that the marine conditions seem to recede to the east in going upwards in the Hampshire Basin. Examination of the plants would lead him to draw the base-line for the Oligocene below the Bournemouth beds. He thought also the evidence of the Mollusca was not entirely opposed to this.

Mr. Whitaker, after speaking of the advantages of the large-scale maps, criticised two of the sections on the wall as difficult to compare. If the introduction of the term Oligocene would save debates about whether a set of beds should be called Lower Miocene or Upper Eocene, it would be a boon, as such debates were profitless.

Prof. Judd said some of the objections now raised reminded him of those brought against Forbes's classification, when he proposed to separate the Headon from the Bembridge series. He was, however, convinced of the accuracy of his views. To Prof. Prestwich he said the amount of the anticlinal had been exaggerated, the distance of the Bembridge limestone from the marine band on Headon Hill did not correspond with the distance at Cliff-end. Just where the Colwell-Bay beds should appear on Headon Hill the ground is wholly masked. In his paper he had referred at length to Dr. Duncan's and Von Könen's work. He agreed that there was not much importance in a name; but the term Oligocene was established on the continent, and it was very desirable to use it. He thought the Upper Bagshot sands which contain *Cerithium concavum* should be grouped with the Headon. He thought it was too late in the day to get rid of the terms Eocene &c. He did not agree with the identification which Mr. H. Keeping had made of the shells he had collected for Mr. Edwards. In reply to Mr. Blake, he said he had paid special attention to the representatives of the same genus in the different beds. As regards Mr. Gardner's remarks, he said the position of the land in Eocene and Oligocene times was quite different; and the line could not be drawn where he placed it, as the limits of the groups were founded, not on terrestrial, but on marine faunas.

13. *On the* Correlation *of the* Drift-deposits *of the* North-west *of* England *with those of the* Midland *and* Eastern Counties. By D. Mackintosh, Esq., F.G.S. (Read January 7, 1880.)

Contents.

Introductory Remarks.

My paper on boulders*, in the Quart. Journ. Geol. Soc. for August 1879, terminated abruptly, owing to my having been advised to postpone the concluding part, on the Correlation of the Drift-deposits, which will form the main subject of this paper. But before dismissing the special subject of boulders, I would refer to a letter received from Mr. Charles Darwin, F.R.S. &c. (who was the first to elucidate the boulder-transporting agency of floating ice), containing an account of the great Ashley-Heath boulder (see p. 442 of paper), which he was the first to discover and to expose, by excavating on one side and beneath it, so as to find that the block rested on fragments of New Red Sandstone, one of which was split into two and deeply scored. I have little doubt that this boulder went south from some of the mountains around Ennerdale, as I have seen boulders resembling it on Dent Hill, near Cleator. The facts mentioned in the letter from Mr. Darwin would seem to show that the boulder must have fallen through water from floating ice with a force sufficient to split the underlying lump of sandstone, but not sufficient to crush it.

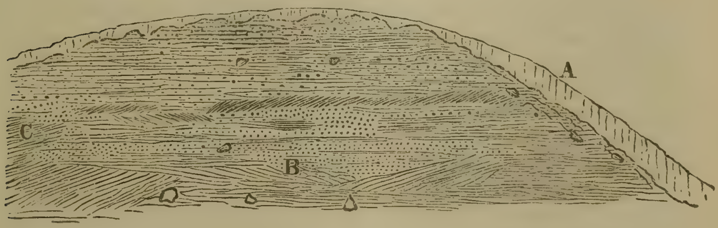
Southerly Extension of the Upper Boulder-clay of Cheshire &c. into South Shropshire.

In the western part of the plain of East Denbighshire and Shropshire the Upper Boulder-clay degenerates into a loamy gravel, which

* At p. 450, line 20 from the top, for "Criffel granites" read "varieties of Criffel granite;" and at line 24 from the top of the same page, for "Boulder-clay," read "Lower Boulder-clay." At p. 453, line 2 from bottom of table, for "mass," read "lower part." At p. 448 I ought to have mentioned that the distinguished local authority on the striated rock-surfaces around Liverpool, Mr. Morton, F.G.S., had recently been led to doubt some of his former opinions concerning their origin, and to favour the theory of floating ice (see Proc. Liverpool Geol. Soc. for 1876–77, pp. 294, 295).

in many places covers the middle sand-and-gravel formation, as around Whittington, Oswestry, &c. South of Ellesmere it capriciously caps the large sand-and-gravel mounds (eskers?), covers portions of their sides, or lurks in the hollows between them; but the sharp line between the upper clay and the underlying gravel or sand, so strikingly displayed all around the Irish Sea, is frequently absent. The subglacial mud, or source of supply in the Lake-district (to which the uniform character of the clay over extensive areas is chiefly owing), would appear to have been carried by the currents which floated the boulder-laden ice in a southerly direction by way of Whitchurch and Shrewsbury to Berrington, where the Upper Boulder-clay is scarcely distinguishable in appearance from the horizontally continuous formation in Cheshire and Lancashire*. In the extensive clay-pits lately opened near the Shrewsbury new barracks the clay is a *facsimile* of the Upper Boulder-clay of Cheshire and Lancashire, and the same in composition with the exception of the absence of lime, which apparently did not find its way from the Carboniferous rocks of the southern border of the Lake-district so far south as Shrewsbury. In these clay-pits there is generally a sharp line between the clay and the underlying *sand*, which in some places is contorted, and which is said to reach a thickness of 90 feet†. Most of the erratics in the clay are from the Welsh borders. Not more than one out of several hundred consists of granite‡. The stones are generally angular or subangular; and exceedingly few of them are flattened or distinctly striated. Near the ferry, a short distance south of the Shrewsbury Welsh bridge, the upper clay, somewhat in the form of a wrapper, covers a large mound of shelly sand and fine gravel, in the lower part of which several granite (Eskdale and Criffel) boulders have been found (see fig. 1). The upper clay, more or less underlain by sand, is well represented

Fig. 1.—*Section near the Shrewsbury Welsh Bridge.*



A. Upper Clay. B. Sand and fine gravel. C. Talus.

* I had not discovered this southerly extension of the upper clay when my paper on sections around the estuary of the Dee (Quart. Journ. Geol. Soc. for November 1877) was written.

† The sand contains streaks and fragments of coal.

‡ Granite, however, is rather abundant in the lower unstratified gravel of the neighbourhood.

between Shrewsbury and Wellington*. From the neighbourhood of Crewe, Cheshire (where it is extensively distributed, in many places over middle sand), it attenuates in a S.S.E. direction along the line of railway, and, so far as I could see, disappears at the waterparting; and on descending towards Stafford, instead of clay over sand-and-gravel, sand-and-gravel over clay gradually makes its appearance. About Stafford, between Stafford and Wolverhampton, and along the North-western Railway for a great distance in a S.S.E. direction, sand is found over clay.

Probable Extension of the Upper Boulder-clay along the Lower Course of the Severn Valley.

It is not necessary to suppose that the maximum surface-level of the Upper-Boulder-clay sea on the north and west side of the great Wrekin and Ashley waterparting was lower than (say) 600 feet above the present sea-level, because an exhaustion of supply from the great northern source would of itself prevent clay from crossing many of the gaps in the waterparting. It is possible it may have found its way through some of them in places to which my observations have not extended; and I have noticed the appearance of a gradually degenerating extension of this clay from Cressage (where it is tolerably represented), through the deep Ironbridge gap, nearly as far south as Bewdley; and it may possibly have found its way still further south. Here and there the clay covers gravel-and-sand with a tolerably distinct line of separation; but in most places it more resembles a clayey wash which has come over and mixed with the upper part of the gravel and sand. The appearance of a surface-clay in the Severn valley, about Buildwas and Bridgenorth, was long ago noticed by Mr. Maw, F.G.S., whose paper in the Quart. Journ. Geol. Soc. (vol. xx.) is full of accurate information and valuable suggestions.

Dispersion of Angular Débris from the Malvern Hills.

In my former paper I suggested the possibility of a supplementary distribution of small northern erratic pebbles along the lower course of the Severn during shallow-water conditions, a few larger stones having *previously* found their way to higher levels at least as far south as Sutton (west of Hampton Loade station), and probably as far south as Apperley Court, south of Tewkesbury. It would appear that there has been a comparatively late dispersion of Malvern syenite (so-called) around the Malvern hills and between the hills and the Severn. This syenite composes an angular drift which overlies all the other deposits, and which extends to low as well as to high levels, as if the dispersion had taken place after the present configuration of the ground had come into existence†. Those who think

* The considerable expanse of clay on Haughmond Hill up to nearly 500 feet above the sea is probably on the same horizon. A degenerate attenuation of it may be traced as far south as Church Stretton; but it is questionable whether it be represented even by loamy gravel as far west as Llanymynech.

† Some years ago I had opportunities of observing many sections of drifts around Malvern, where now very few are exposed.

that this uppermost drift could only have been distributed by a cause operating independently of the hills, will require to have recourse to the idea of a late submergence of the land, which may have been brought about by a southerly extension of the Upper-Boulder-clay sea. Others may agree with the eminent local authority, the Rev. W. S. Symonds, F.G.S., in believing that floods, caused by the sudden melting of snow and ice on the Malvern hills, may have been sufficient to scatter the rock-fragments. I have been led to believe, from Mr. Symonds's observations, that Malvern-hill débris may have been previously distributed, during the accumulation of the high-level clays and gravels, which (from the latter consisting to a great extent of Triassic pebbles) may possibly be on the horizon of the somewhat similar drifts between Wolverhampton and Bridgenorth, which contain northern granite boulders*, and are probably equivalent to the Lower Boulder-clay further north.

Low-level Drifts South of Worcester.

According to Murchison, Strickland, and Falconer, the following would appear to be the *descending* order of deposits near the river Severn south of Worcester:—

1. Coarse gravel, with blocks of Malvern-hill syenite† and northern granite pebbles.
2. Estuarine sand and drift gravel, with *Elephas primigenius*, *Rhinoceros tichorhinus*, reindeer, &c., and sea-shells, including *Bulla*, *Ampulla*, and *Oliva*, in addition to shells now found around our shores.
3. Fluviatile deposit, with freshwater shells and *Elephas antiquus*, *Hippopotamus major*, &c.
4. Red marl.

No. 1 may possibly have been deposited during the northern Upper-Boulder-clay submergence. No. 2 may have been deposited towards the close of the first submergence, and may represent the middle sand and gravel of the north. The three shells now found in warm latitudes (if correctly identified) might be regarded as indicating a mild interglacial period. In the section there is nothing to correspond to the Lower Boulder-clay of the north; but it ought to be recollected that in the midland counties, and even in the north, it is often represented by gravel, and in some places not represented at all. The low level at which the fluviatile deposit occurs near the present channel of the Severn (the estuarine shell-bed above it being not more than 30 ft. higher than the river) seems to show that in preglacial times the level of the river was very nearly as low as at present, thus indicating that the Severn valley, with its wide alluvial flats, may have been excavated in preglacial times—in this respect corresponding to the northern valleys. It is at the same

* As stated in my former paper, granite boulders were found in high-level drift at Apperley Court.

† The Rev. W. S. Symonds has elsewhere found Malvern-hill débris covering up the remains of extinct Mammalia; and the fact certainly lends support to the idea of an interglacial period, during which the animals lived, succeeded by a return of cold conditions, which caused their extinction.

time possible that the river in preglacial times may have been chiefly occupied in deepening its channel, and that the process of widening, by lateral undermining, may have chiefly occurred in interglacial and postglacial times—in other words, after the accumulation of the high-level drifts.

Redistribution of Triassic Pebbles.

It is well known that south and south-east of the Wrekin and Ashley waterparting (as well as around the waterparting itself) there are extensive Triassic pebble-beds, which have been broken up and redistributed in a S. and S.E. direction, probably for the most part by oceanic currents and waves; for it would be unreasonable to suppose that all the great and often continuous spreads of pebbles could have been uprooted and transported by floating ice. Along with Scottish, Cumbrian, or Welsh erratics, they may be seen imbedded in clay, loam, or sand at least as far south as Bromsgrove*. Their distribution must therefore have taken place during a part, if not the whole, of the period of the great northern boulder-dispersions. It is worthy of remark that in the neighbourhood of the lower course of the Severn many sections of *so-called* drift consist of Triassic pebbles *in situ*. A notable instance of this may be seen in Spring-Hill gravel-pit, between Bewdley and Kidderminster, which contains no drift belonging to the glacial period excepting a few local fragments on the surface and the harder parts of limestone burnt for manure (?). It is likewise worthy of remark that many published sections of quartzose and flinty gravel are calculated to mislead, because their details show no greater changes of conditions during their accumulation than often take place in a few days on a sea-beach subjected to alternate denudation and deposition.

Drift-deposits of the East-Midland Counties.

As may be gathered from my former paper, the area between Wolverhampton and Stafford may be regarded as the meeting-ground of erratics from the N.N.W. and of erratics from the E.N.E., the former chiefly granite and felstone, and the latter chiefly Cretaceous and Jurassic débris. Over this meeting-ground both sets of erratics would appear to have been precipitated into a drift-matrix resulting from a submergence which extended round the Pennine hills from the source of the N.N.W. erratics to the source of the E.N.E. erratics. From the area between Wolverhampton and Stafford the deposit with Cretaceous and Jurassic débris (after losing its erratics from the N.N.W.) extends over the east-midland counties until it graduates into the Chalky Clay, thus rendering it probable that the Chalky Clay is on the same horizon with the deposit containing erratics from the N.N.W. between Wolverhampton and Stafford.

* Besides large boulders, I saw many pebbles of Arenig felstone imbedded, along with Triassic pebbles, in loamy clay or sand between Hagley and Catshill. Mr. Amphlett, of Clent, tells me that these drifts are sometimes separated from the underlying rock by a distinct line of demarcation.

This deposit I have hitherto been led to regard as a southerly continuation of the Lower Boulder-clay of Lancashire, Cheshire, &c. (see my former paper, and the concluding part of this paper).

Drift-deposits around Nuneaton, Coventry, Kenilworth, and Leamington.

In this area the drift-matrix consists of redistributed local shale, clay, or marl belonging to the Triassic, Permian, or Carboniferous formations. The stones, in addition to quartzose and other pebbles, consist of flints, a few chalk fragments, and erratics from the Pennine hills, Charnwood forest, Hartshill, and fragments or fossils of Jurassic rocks. These erratics (which chiefly came from the north and east) are commonly imbedded in what is locally called "top clay," of a brown or red colour, which graduates downwards into underlying marl, shale, &c. This clay contains chalk flints (rather fitfully distributed, but generally very little chalk débris. In one of the Kenilworth gravel-pits the redeposited Triassic pebbles, intermixed with large angular chalk flints and coal-dust, graduate downwards into a pell-mell local boulder-loam, which is probably the equivalent of the Wolverhampton and Stafford Boulder-clay. At Lillington, near Leamington (in 1865), the red marl, with a few stones near its surface, was overlain by a mass of stratified fine gravel, consisting of Triassic pebbles, *Gryphites*, &c., above which there was a considerable thickness of obliquely laminated fine sand, surmounted by 2 feet of clay with pebbles (see fig. 2). In 1878 no section was exposed lower down

Fig. 2.—*Section at Lillington, near Leamington.*

A. Compact clay. B. Laminated Sand.
C. Fine gravel. D. Red marl.

than the fine sand. At the Stoke-Heath clay-pits, near Coventry, the clay (which contained a large boulder, probably from Charnwood forest) here and there graduated into gravel on the same horizon, and contained a few (but only a few) chalk-fragments and chalk-flints. Around Nuneaton the clay (with "trap" boulders) contained many flint chips and small Triassic pebbles, but scarcely any chalk; and the specimens of the clay I brought away with me did not effervesce with ordinary tests. Near Rugby railway-station (March 1879) the matrix of the drift seemed to be locally derived clay, chiefly of a red or brown colour, with great masses of chalk imbedded and partly dispersed through the clay. As some interest attaches to the western boundary of what may be called the true Chalky Clay, I may state that I agree with Mr. Harrison, F.G.S., in believing that it does not extend further west than Charnwood forest; and I likewise believe that for a considerable distance east of that boundary the clay itself is of local derivation, and that the chalk-fragments, however numerous or large, are erratics dropped into the clay by floating ice. The occurrence of local, indirectly local, or erratic stones in locally worked-up shale, marl, clay, &c. is a phenomenon not confined to the midland counties of England. It may be seen exemplified around Matlock, Belper, &c., southward across the central plain of England as far, at least, as the Jurassic escarpment, south-westward at least as far as Usk, Monmouthshire, and westward along the Welsh valleys as far as St. George's Channel.

Drift-Deposits of Leicestershire, Rutlandshire, &c.

Professor Judd, in his Survey Memoir on the geology of the area lying between some of the districts above noticed and Lincolnshire, describes the Boulder-clay as being often underlain by sand and gravel (with brick-earth), and covered by gravel-beds, which are partly interstratified with the upper part of the Boulder-clay. These gravel-beds consist of stones which were derived from the Boulder-clay. The clay contains more and more chalk-fragments and flints eastwards, until in some places it becomes almost reconstructed chalk. Professor Judd in places found the clay graduating into gravel on the same horizon, as if the supply of clay had become exhausted while the stones continued to be carried forward. I had previously noticed a similar gradual replacement of clay by stones, but never fully understood it until I had read Professor Judd's explanation, which ought never to be forgotten in tracing Boulder-clays to greater or less distances from their sources of supply. He describes enormous boulders of oolite and marlstone, one of them (on Beacon Hill) being 600 feet in diameter, and refers their transportation from their parent rocks to the period of the glacial submergence. They are found in the lower part, as well as on the surface of the Boulder-clay, This clay would appear to be horizontally continuous with the great boulder-bearing clay and gravel in the neighbourhood of Wolverhampton. In the British-Association Boulder Report for 1878, Mr. Molyneux, in describing the boulders west of Burton-on-Trent, says:—"The boulders or rock-masses occur principally at from three to ten feet below the surface, intermixed with blue and yellow clay, and consist of angular, subangular, and rounded fragments of Carboniferous limestone and chert, Yoredale Sandstone, Millstone Grit, ranites [from the Charnwood or Mount-Sorrel district—D. M.], porphyry, syenite, greenstone," &c., "with smaller fragments of Liassic and Oolitic rocks." In many parts of the eastern midland counties there is a considerable thickness of gravel or sand above the horizon of the clay with chalk débris.

Drift-Deposits around Gainsborough.

At Gainsborough and southward, though at no great distance from the Lincolnshire chalk-wolds, I saw a clay of varying colour graduating downward into the underlying marl of Triassic or subsequent age. On the summit of the Triassic escarpment it mainly consisted of directly worked-up gypseous marl, with a considerable quantity of chalk débris, which, however, was nowhere thoroughly incorporated with the clay itself—so little so that the greater part of the clay would not effervesce with ordinary tests. The chalk was not a constituent of the clay, but an addition. The clay, along with the chalk erratics, contained Bunter pebbles, fragments of Carboniferous rocks from the Pennine Hills, igneous and metamorphic rocks including gneiss (from Norway?). It was covered with, or graduated upwards into, sand, with Bunter pebbles, wholly or partly derived from the clay. Between Retford and Bawtry, as may be seen in the railway-cuttings, there are beds consisting of rearranged Bunter pebbles and sand, which contain a few chalk-flints, but very few other erratics. This gravel-and-sand is apparently on the same horizon as the Gainsborough sand, and in places is covered with a clayey wash which may be a southerly attenuation of the Hessle clay of Yorkshire. The underlying gravel-and-sand may represent the great gravel-and-sand formation around York, under or in the lower part of which comes the remarkable lenticulation of laminated stoneless clay, and under this the "carrion," which is a clay or loam with boulders of Millstone Grit and Mountain Limestone from the Pennine Hills, and which can be traced westward through gaps in these hills. Its relation to the purple-clay of East Yorkshire is still uncertain*.

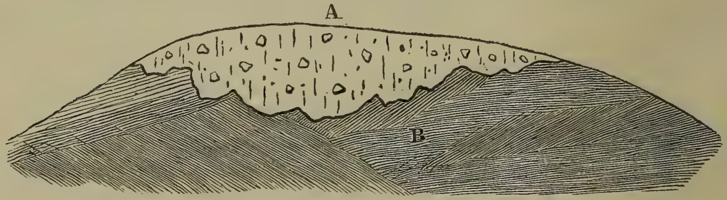
Correlation of the Drift-Deposits of W. Yorkshire with those of Lancashire and Cheshire.

In 1867–70 I endeavoured to trace the connexion between these deposits by way of the Aire and Wharfe valleys and the plain of Craven. I was fortunate in meeting with many clear sections during the drainage of towns and excavations for house-sites; and the results were very briefly stated in a paper which appeared in the 'Proceedings' of the West-Riding Geological and Polytechnic Society. Lowest of all is the blue clay, which nowhere rises higher

* In the western part of the vale of York, Jurassic débris from the north or east are associated with Millstone Grit and Mountain Limestone from the west; and Gryphites have been reported as having gone far up the valley of the Aire; but as the Rev. N. Tute found Lias fossils near Leeds, which had been brought as railway ballast from the foot of the Hambleton Hills, little reliance can be placed on such reports. There can, however, be no doubt that Mr. Tute found Shap granite in the yellowish-brown clay which overlies the very dark-coloured or blue clay west of Ripon. After crossing Stainmoor, the Shap granite may have gone south by Richmond to the neighbourhood of Ripon. The precise position of Shap boulders in the drift-deposits of the east coast of Yorkshire has not, I believe, been yet ascertained. Granite from the south of Scotland has been found on the coast near Scarborough; but whether it accompanied the Shap granite over Stainmoor, or went east along the upper course of the Tyne, and then south-east, it might be difficult to ascertain.

than about 600 ft. above the sea-level, which contains many glaciated stones, and which, I *now* believe, may have been accumulated under land-ice. The yellow or yellowish-brown clay above it rises to much higher levels, contains fewer glaciated stones, and differs from the blue in the kind of boulders or relative percentage of different kinds of boulders it contains. Above the brown clay, at intervals, there is a great thickness of sand or gravel, which often forms esker-like mounds, as in the neighbourhood of Esholt and Bingley, in the valley of the Aire. In the plain of Craven the numerous large and curvilinear mounds, which have been regarded as glacial moraines, may be seen in sections to consist of sand or clay with numerous well-rounded and evidently waterworn stones. Between York and Lancaster, by way of the Aire or Wharfe valleys and the plain of Craven, the sand and fine gravel (which are scarcely ever found at high levels) were probably not distributed until after the emergence of the higher parts of the Pennine Hills—in other words, until the valleys had become converted into straits and sea-lochs. As may often be seen in Cheshire and Lancashire, there is sometimes in the West Riding the appearance of a cleanly-eroded surface of sand or fine gravel unconformably overlain by clay, loam, or coarse gravel, with good-sized boulders. At Marley sand-pit, near Keighley, sand at least 20 ft. thick is unconformably surmounted by 10 ft. of loamy clay, with striated boulders (see fig. 3) up to 2 ft. in diameter (1870). North

Fig. 3.—*Section in Marley Sand-pit, near Keighley.*



A. Upper Boulder-clay. B. Sand and fine gravel.

of the White Hart Inn (between Aberford and Bramham) a bed of dark clay and sand is covered with sand and gravel which had evidently been eroded before the deposition of a capping of reddish clay with boulders. Other instances might be stated. I have not had an opportunity of ascertaining how far these Upper Boulder-clays may represent the Hessle clay of East Yorkshire; but I believe they are on the same horizon as the much more continuous Upper Boulder-clay of the plain of Lancashire and Cheshire and of the valleys on the western side of the Pennine Hills.

Concluding Remarks and Suggestions.

After much consideration and correspondence with geologists, I have been induced to leave open the question of the correlation of the Norfolk "till," Middle Glacial sand, great Chalky Clay, purple clay, Hessle sand, and Hessle clay of the east with the Lower blue and brown Boulder-clays, Middle sand-and-gravel, and Upper Boulder-clay of the north-west. In all attempts to correlate these deposits, it ought not to be forgotten that the lower brown clay and upper clay of the north-west maintain very much the same character (irrespectively of the subjacent rocks) over extensive areas, and that this is especially the case with the upper clay, which, with extremely little variation, extends along certain lines continuously from at least as far north as Carlisle to Berrington, south of Shrewsbury (about 160 miles), and from the neighbourhood of Glossop as far west at least as Menai Strait (about 100 miles); in other words, the Upper Boulder-clay of the north-west (especially if we make allowance for the great mass of it which in all probability runs under the Irish Sea) covers an area equal to that of the Chalky Clay of the east; but the Chalky Clay differs very much from the upper clay of the north-west in frequently varying its character with the rocks on or near to which it rests, and likewise in often attaining a much greater thickness than the upper clay of the north-west, which is more a *wrapper* than a *leveller* of preexisting inequalities. There is a bare possibility of the drift with many large boulders around Wolverhampton (which, in an easterly direction, seems to graduate into the Chalky Clay) being of the same age as the upper clay of the north-west (which approaches at least as near to Wolverhampton as Wellington); and if so, the upper clay of the north-west may represent the Chalky Clay of the east. But three facts would appear to militate against this idea:—(1) the upper clay of the north-west, unlike the Wolverhampton clay, contains exceedingly few large boulders*, as may be seen in the numerous and extensive excavations lately made for obtaining brick-clay; (2) the existence of extensive gravel-beds in the east-midland counties (though not in East Anglia) *above* a more or less chalky Boulder-clay, which are not represented above the upper clay of the north-west †; (3) the difference in character between the middle non-glacial sand of the north-west, with no contemporaneously transported erratics (excepting near the mountains), and the middle glacial sand of the east, with many contemporaneously transported erratics ‡. Some time ago I corresponded for several years with Mr. S. V. Wood, F.G.S., on the subject of the correlation of the drifts of the north-west and east. He then regarded the purple clay of E. Yorkshire (which is horizontally continuous with the Chalky Clay of Lincolnshire) as the oldest deposit in the east with which the lower brown

* An exception, however, to this general rule, was lately met with in the Bootle-Dock excavations, near Liverpool, where many large boulders of dolerite and diorite ("greenstone"), from the south of Scotland, were found.

† It ought, however, to be recollected that, on the same principle, the theory which synchronizes the Chalky Clay of the east with the Lower Boulder-clay of the north-west would require an adequate representation of the middle glacial sand of the east under the lower clay of the north-west, which is not to be found.

‡ See Mr. Penning's paper on the Physical Geology of East Anglia &c., Quart. Journ. Geol. Soc. for May 1876.

clay of the north-west could be correlated, and seemed inclined to the opinion that the Hessle clay of Holderness might represent the upper clay of the north-west, as both were characterized by grey or ash-coloured vertical fractures. But I was not then aware of the southerly extension of the upper clay of the north-west, or of its extreme range of altitude, which reaches quite 600 ft. in a typical form, and probably from 700 to 800 ft. in a degenerate and attenuated form. The question remains as to the age of a great sheet of chalkless clay which Mr. Wood lately found extending northward from York through Durham (Geol. Mag. for Jan. 1878). Should this clay prove to be of Hessle age, the Hessle clay might then be regarded as extending from the Wash* to the river Tyne, and therefore more likely to be the equivalent of the upper clay of the north-west than if it had been entirely limited to Holderness and the immediate neighbourhood.

Note.—In this paper I have made very little reference to the evidence of the relative age of deposits furnished by Mollusca, because I do not consider it in all cases reliable. Mr. S. V. Wood, Jun., F.G.S., believed that the lower brown clay of the north-west could not be older than the upper part of the purple clay (above the chalky clay) of the Yorkshire coast; but he relied on shells found in intercalations of sand, consisting of a mere streak at Dimlington, and at Bridlington of a very limited bed in the midst of large boulders, the latter suggesting the possible flotation by ice of the shell-bearing sand from an older deposit.

* See Mr. Jukes-Browne's paper on the Southerly Extension of Hessle Boulder-clay in Lincolnshire, Quart. Journ. Geol. Soc. for August 1879.

14. *On the* Portland Rocks *of* England. By the Rev. J. F. Blake, M.A., F.G.S. (Read January 7, 1880.)

[Plates VIII.–X.]

Unlike the Kimmeridgian and Corallian rocks, the Portland series has been frequently examined in all its localities by competent observers, and there might seem, at first sight, to be little additional or desirable information to obtain. Yet when all the extant materials are put together they seem to serve but slightly towards the history of the deposits in their varying relations to each other and to similar rocks abroad. There is first the masterly work of Fitton, forming the basis of our present knowledge; yet many questions have arisen since its epoch which wait for a reply. The typical sections along the coast have been touched on by several authors—as Buckland and De la Beche*, Bristow†, and Damon‡; and the Portland stone has been well described; but the lower part of the series has been neglected. The district of the Vale of Wardour has attracted little attention, though it has been mapped by the officers of the Geological Survey. Of the important exposures in the neighbourhood of Swindon many descriptions have been given§; but they do not agree with each other, and are all defective. Little addition has been made to our knowledge of the Oxfordshire and Buckinghamshire area, although Prof. Phillips in 1871|| added the names of several and the figures of a few species from the series, which he took no pains to compare with those of foreign authors. The most important event in relation to these rocks was the visit of M. Sæmann to this country in 1865. He was struck by the resemblance of the fossils of the Hartwell clay to those of parts of the Boulogne cliffs to which had been assigned the name of Middle Portlandian; and M. De Loriol¶, after an examination of the series of fossils from this locality and from Swindon, identified many as French species; and his co-author M. Pellat stated that the clay of Hartwell should be called Middle Portlandian, and that the Lower Portlandian is absent from England. These statements have been most useful as opening up questions of the highest interest; for it has been necessary to inquire with what right the name of Portlandian has been adopted in France, and whether any part of the series is absent from England, and thus to reexamine some portion of the Kimmeridge Clay.

In our introduction to the "Corallian Rocks of England"** Mr. Hudleston and I regarded the series we were about to describe as a

* Trans. Geol. Soc. 2nd ser. vol. iv. p. 17.

† Geol. Surv. Horizontal Sections, Sheet 56.

‡ Geology of Weymouth.

§ Godwin-Austen, Q. J. G. S. vol. vi. p. 454, Mem. Geol. Survey, Sheet 34; Proc. Geol. Assoc. vol. iv. p. 543.

|| Geology of Oxford and the Valley of the Thames. See also Wright, 'British Fossil Echinoderms,' and Lycett 'The Fossil Trigoniæ,' Pal. Soc.

¶ Mémoires de la Soc. Phys. et Hist. Nat. de Genève, tome xix.

** Quart. Journ. Geol. Soc. vol. xxxiii. p. 261.

local development in a great pelolithic formation, and deprecated the extension of the name "Corallian" to beds of probably various ages, which only agreed with our own in occurring in the Oxford-Kimmeridge seas, and in containing corals. Just the same might be said of the Portland rocks; only I should now express it differently. The "normal"* deposits throughout the European area in the later Jurassic times were argillaceous; and in England we have two important "episodes," the Corallian and the Portlandian. In the various countries of the continent they also have episodes, two, or more than two; but how far they agree in age with ours has yet to a great extent to be determined. At present all the later ones have been called Portlandian; and thus confusion has arisen. I shall now endeavour to show that, as far as the rocks which have been called Middle and Lower Portlandian at Boulogne are concerned, their normal representatives exist in the mass of the Kimmeridge Clay, and are rightly classed as part of that formation—and also to describe the relations of the various parts of the true Portland episode to each other, and thus to obtain an insight into those final oscillations which converted the open argillaceous ocean into the lake-bearing and cycad-growing continent of the Purbecks.

1. *The Island of Portland.*

It will first be necessary, at the risk of repeating well-known facts†, to describe in detail the typical section in the Isle of Portland, in order to place in their proper relation facts which are not so well known. Fig. 1 (Pl. VIII.) gives the generalized section of the several exposures in the island.

The line of demarcation between the Portland and the Purbeck is very clear and constant, consisting of a layer of clay, not lying exactly on an eroded but on a very uneven surface. The lower Purbeck beds known as the "Cap" and the "Skull Cap" are botryoidal limestones or indurated calc-tuffs. They have therefore been derived from the denudation of the Portland rocks which had elsewhere emerged from the sea at an earlier date, though here the emergence had been so recent that very little atmospheric action had occurred. The separating layer, however, contains *remaniés* Portland flints. This gives us the expectation of finding here a more complete development of Portland rocks than at such places as show more erosion.

No. 1 is the "Roach," which may be characterized as a shell-limestone. It is to be noted that throughout it is distinctly oolitic, and especially so at the top; it contains chalcedonic masses which can scarcely be called flints. It is so variable in thickness and so incorporated with the bed below that it must be taken as forming part of it. The shells which characterize this are:—first, the *Cerithium portlandicum*, which is not, to my knowledge, found in any other

* See my paper on Geological Episodes, abstracted in 'Nature,' Sept. 4, 1879.

† Damon's description of these beds is most accurate, and draws attention to points which are insisted on below.

bed in Portland; *Sowerbya Dukei*, and *Buccinum naticoides* appear also to be peculiar, though infinitely more rare.

The *Trigonia gibbosa**, *Lucina portlandica*, *Pecten lamellosus*, *Ostrea expansa*, and *Natica elegans*, it retains from earlier times; but *Cardium dissimile* appears to have died out.

No. 2 is the "Whit bed," whose qualities have made the island so famous. The difference in its thickness in the different quarries has long been noticed, especially its increase towards the west. The fact is, it may be seen dying out, and very false-bedded if traced beyond the quarries to the east. It is not properly oolitic, and contains very few fossils. The true *Ammonites giganteus* appears, however, to be peculiar to it, those so called from other beds belonging to distinct species. These uppermost beds are thus proved local, even in the Island of Portland itself. The fact that they do not occur elsewhere on the coast or at Upway in the same character, while the Purbecks remain similar, indicates some slight amount of unconformity between the two series. The Roach and Whit bed are also, it would seem, separated by unconformity, or at least contemporaneous erosion, from the beds below, and thus constitute a stage in the episode of a very marked character.

Nos. 3–9 may be characterized as the flinty series. No. 3 is the "Curf," which varies in inverse proportion to the Whit bed, as though the erosion of one had formed the basin for the other. It is also oolitic, and contains, according to Damon, abundant *Ostrea solitaria*.

No. 4 is the "base"-bed, which, though very like the Whit bed in appearance, is distinguishable from it by the presence of strong irregular bands of flint. This and No. 3 are the home of the rare *Isastræa oblonga* and its perforating *Lithodomi*. The rarity of corals may account for the scarcity of oolitic rocks.

No. 5 and those below cease to have workmen's names applied, as they are not quarried. The upper block is full of *Trigonia gibbosa*, and may be named the *Trigonia*-bed. It is of so changing a thickness as to suggest its being deposited on an uneven surface. In one place it is seen lying on No. 6, and is not more than from 4 to 6 feet in thickness; whilst in the great cutting of the Verne Fort, further to the north, it cuts irregularly into No. 8 and reaches nearly 20 feet. At this spot it has been compared by Damon to the Roach, from which, as he remarks, it may be distinguished by the change of fossils, *Perna mytiloides* taking the place of *Cerithium portlandicum*.

No. 6 is a remarkable mass about 3 feet in thickness. The upper part is solid flint; but the lower part is a rubble-bed, made of broken masses of limestone like the beds below, with a siliceous cement. Here is another evidence of the irregularity with which the final changes took place, which warns us that Nos. 3 to 5 may represent another local deposit.

No. 7 requires distinction, though essentially part of No. 8, be-

* I cannot appreciate the differences which have led Messrs. De Loriol and Lycett to establish a new species (?) *T. Damoniana* for these; the varieties pass indefinitely into each other.

cause the lower part is so full of *Serpula gordialis* as to almost merit the title of Serpulite. It also contains abundance of *Ostrea multiformis*. It serves as a guide in strictly local correlation, though it would be absurd to suppose all Serpulites, even if of the same species, to be necessarily continuations of the same deposit. To this portion, which is more free from flints, a thickness of 6 feet may be assigned.

No. 8. This constitutes the main mass of the flinty series; the layers are irregularly spaced and of various thicknesses; some portions of these are false-bedded; and it is more chalky than the beds above No. 6. Fossils are rather scarce; but on the surface of the blocks are fucoid markings, and there are numerous specimens of rather large Ammonites—the *Am. boloniensis* of De Loriol, which is easily distinguished from *Am. giganteus* by its shape and the regularity of its rib-bifurcation. Here also we find associated with *Trigonia gibbosa* the *T. incurva*, which, as it does not ascend into the higher beds, indicates a rather lower horizon everywhere. There is also a broad *Perna*, like *P. Flambarti*. These fossils are chiefly found in the block at the base, which is more brashy, and has a thickness of 1 foot 8 in. Including this the series is about 26 feet thick.

No. 9 is a shell-bed. It abounds in small oysters and *Serpulæ*; but *Trigoniæ* are not more abundant than other fossils. As it supplies us with the fauna of the flinty series, it is of great importance, though it has been by no means thoroughly searched. The most noticeable are:—*Ammonites pseudogigas*, which has great nodosities like *A. gigas*, but they are more numerous; *A. triplex*, a very characteristic form; *Pleurotomaria rugata* and *P. Rozeti*, the latter being met with in the so-called Middle Portlandian of Boulogne; *Cardium dissimile*, which thus appears to mark a lower than the highest horizon at Portland; *Cyprina elongata*, a new species, but found elsewhere; *Lima rustica*, *Pecten lamellosus*, *Trigonia gibbosa* and *T. incurva* and probably other species; and in places abundance of *Pleuromya tellina*, whose place in the series at Portland it is important to fix. The thickness is 7 feet 6 inches.

These nine are the Portland Stone; and it appears that they form two subdivisions, separated from each other by their stratigraphy, lithology, and fossils, though forming part of the same general series. The upper may be called the Building-stone, and the lower the Flint-beds. The total thickness of the former may be put at a maximum of 12 feet, while the latter is about 68 feet, and is divisible into two slightly unconformable masses.

The rocks which succeed the Portland Stone in a downward direction, beyond being called the Portland Sand, have been but little noticed, though they are not inaccessible or uninteresting, and afford valuable means of correlation.

No. 10 is a stiff blue marl of a thickness of from 12 to 14 feet, in which I have not succeeded in finding any fossils; but which from its mineralogical character (so different from that which one might expect from the title Portland Sands), and from similar occurrences elsewhere, is an important bed.

No. 11 consists of about 26 feet of very curious material: it is a liver-coloured mixture of marl and sand, with isolated nodules and thick continuous bands of a sandy cement-stone. The fossils in these cement-stones are not numerous, but they are useful ones. We find here *Mytilus autissiodorensis*, which occupies the same horizon, both elsewhere in England and at Boulogne, with *Pecten solidus*, *Cyprina implicata* (as at Boulogne), *Cyprina elongata*, an *Isocardia*, and *Ammonites Boisdini* (?) and *A. biplex*.

No. 12 is a perfect lumachelle of small oysters, the *Exogyra bruntrutana*. These exclude all other shells, and by themselves form the mass of the rock with a marly infilling. It is 7 feet thick.

No. 13 consists of 10 feet of yellow sandy beds with hardened bands clearly marked off form the bluer beds below. They contain but few fossils beyond *Cyprina implicata* and an *Arca*.

No. 14 is a mass of sandy marl, gradually changing into true Kimmeridge Clay, the probable junction being inaccessible or covered. More of this can be seen on the western side than beneath Verne Fort, where all the other members are better observed. At least 30 feet are exposed for examination; but there may be much more. They are speckled blue and yellow, and have many small-sized doggers towards the upper part, but larger ones below. A good series of fossils might be collected from this mass; those I have noted are of great value for correlation; they are:—the true *Ammonites biplex*; an ornamented new species of *Natica*, which I call *incisa*; *Lima boloniensis*, which marks a special horizon at Boulogne; *Pecten Morini* and *Avicula octavia*, very characteristic forms; *Trigoniæ incurva*, *muricata*, *Pellati*, and a new undulate species (though there is a total absence of *T. gibbosa*); also two new Brachiopoda (the first hitherto recorded from British Portland rocks), *Rhynchonella portlandica* and *Discina Humphresiana*. *Pleuromya tellina* also occurs, occupying the vertical position.

In all this series (Nos. 10–14), which constitutes the "Portland Sand," I have not seen any glauconite, nor are there any pebbles to my knowledge; but a gradual change is demonstrated —undisturbed by local variations, and only exhibiting the disturbances elsewhere by slight alterations in the character of the deposits. The fauna, though connected with that of the Portland Stone, is more allied to that of the upper part of the Kimmeridge Clay—a fact of which, in my opinion, the French geologists make an inverted use.

2. *St. Alban's Head and Kimmeridge* (fig. 2, Pl. VIII.).

A comparison of the above typical section, derived from both the east and west sides of the isle (between which, in the lower parts, there is little difference), with the development twenty miles to the east, will give an idea of the rapidity with which changes are taking place.

The great quarries on the coast to the south of Worth Maltravers give admirable sections of the upper beds. The botryoidal Purbeck limestone and underlying shale are at once recognized; and then

No. 1 is a creamy limestone, with *Trigonia gibbosa* and *Pecten lamellosus*, about 9 feet 6 inches thick. It has yielded a Brachiopod like *Waldheimia boloniensis*.

No. 2 is a vacuous bed, like the roach, with casts of the *Trigonia* and *Perna mytiloides*, 4 feet 8 inches.

No. 3 forms parts of No. 2, but is clearly separated below. It is an oolite with a shell-band, with *Pernæ* towards the top and bottom, 5 feet.

These three are the only possible representatives of the building-stones. In the absence of flints and in the character of the rock there is similarity. In the want of the characteristic shell, *Cerithium portlandicum*, and the abundance of the *Pecten* and *Perna* found in Portland on lower horizons, there is so much difference as to lead to the conclusion that these are either continuations of the flinty series or deposits in a separately eroded area.

Following these are :—

No. 4. A brownish-weathering, suboolitic block, 8 feet in thickness, the upper part full of *Trigoniæ*, and a few flints near the base.

No. 5. A band of flinty rock, varying from 2 feet 6 inches to 4 feet, with an irregular base filled with indurated clay.

No. 6. A solid suboolitic rock, 8 feet 6 inches thick. The grains are very coarse, and broken shells very numerous, with *Trigoniæ*.

These appear to represent the base-bed and *Trigonia*-bed of the island under a slightly different form. The latter were deposited on an eroded surface formed at the expense of the succeeding rock.

This, No. 7, is a valuable building-stone, for which the quarries are worked. It is a fine-grained suboolitic rock, with few fossils, rather flinty towards the base, and about 10 feet thick; it is followed by

No. 8. A brown sandstone, 1 foot 6 inches. Had these occurred in the island, they would doubtless have been worked towards the north-east corner; but they occupy the interval between No. 5, the *Trigonia*-bed, and No. 7, the Serpulite, of the typical section, though they are scarcely equivalent to No. 6, which represents the result of their contemporaneous erosion.

No. 9 may be taken as 16 feet, all of which is very flinty; it is full of fucoids, and has, towards the middle part, as great an abundance of *Serpula gordialis* as at Portland. *Ammonites boloniensis* is also abundant.

No. 10 constitutes the main mass of the flinty series, and forms the capping of St. Alban's Head and the cliff facing west. It is not very accessible; but I have measured 50 feet, which includes a shell-bed at the base, like that in Portland; the rest is very unfossiliferous, and, after exposure to the sea, has much the aspect of a calcareous grit, there being much siliceous matter even between the flints.

A comparison of the total result at this spot with that in Portland shows that the only possible representative of the building-stone is swollen to 19 feet by the addition of a higher bed (if this be the right interpretation), while the flinty series has expanded to

98 feet, partly by the intercalation of new beds and partly by the thickening of the rest.

In the Portland-sand series the peculiar features of the island are not repeated: the clay band at the top cannot be recognized; and the oyster-bed is certainly absent. Thus the whole might be described as sandy marl with indurated bands. The parts, however, of the series have characters by which correlation is made possible, and a proof afforded that much more is here visible.

Thus No. 11 consists of 39 feet of the liver-coloured mixture, which indurates into two blocks of sandy cement-stone. Above the upper block should be the clay; but it is scarcely less sandy than the rest. *Ammonites biplex* and *Mytilus autissiodorensis* are here abundant. There are also *Pecten solidus*, *Trigonia incurva*, *T. Pellati*, and another species more nearly allied to *T. gibbosa*.

No. 12 shows no particular change at the top; it is all dark, hard, sandy marl, with numerous small cement-stones, lying in bands, and the two lower bands uniting into continuous beds. This contrasts well with the overlying series, and has a thickness of 42 feet. *Exogyra bruntrutana* is scattered throughout this and the next.

No. 13 is a strong band of cement-stone, with abundance of *Thracia tenera* and some other ill-recognizable fossils, 2 feet.

No. 14. Another mass of indurated sandy marl, 30 feet in thickness, and containing *Rhynchonella portlandica*.

No. 15. Another, but thicker, cement-stone, nearly 5 feet. This is probably nowhere exposed in Portland.

No. 16 may be taken as the rest of the sand, the line of separation between it and the Kimmeridge Clay being more or less arbitrary. There are indurated bands, and more marly beds, which throw out the water. In the lowest of the subdivisions thus made, but nearly 40 feet from the base of the whole, *Lingula ovalis* is rather abundant, which seems to me a significant fact. The total amount of this No. 16 is about 126 feet.

Adding the thicknesses of these several beds, we arrive at 244 feet, which is demonstrated to be not far removed from the true thickness of the Portland Sand here. If this seems extravagant it may easily be checked. The height of the cliff is about 500 feet. It is capped by 50 feet of Portland Stone; and my former estimate of the Kimmeridge Clay, taken from the same limiting line to the base of the cliff, was 173 feet, which would leave 277 feet for the Portland Sand if all were horizontal.

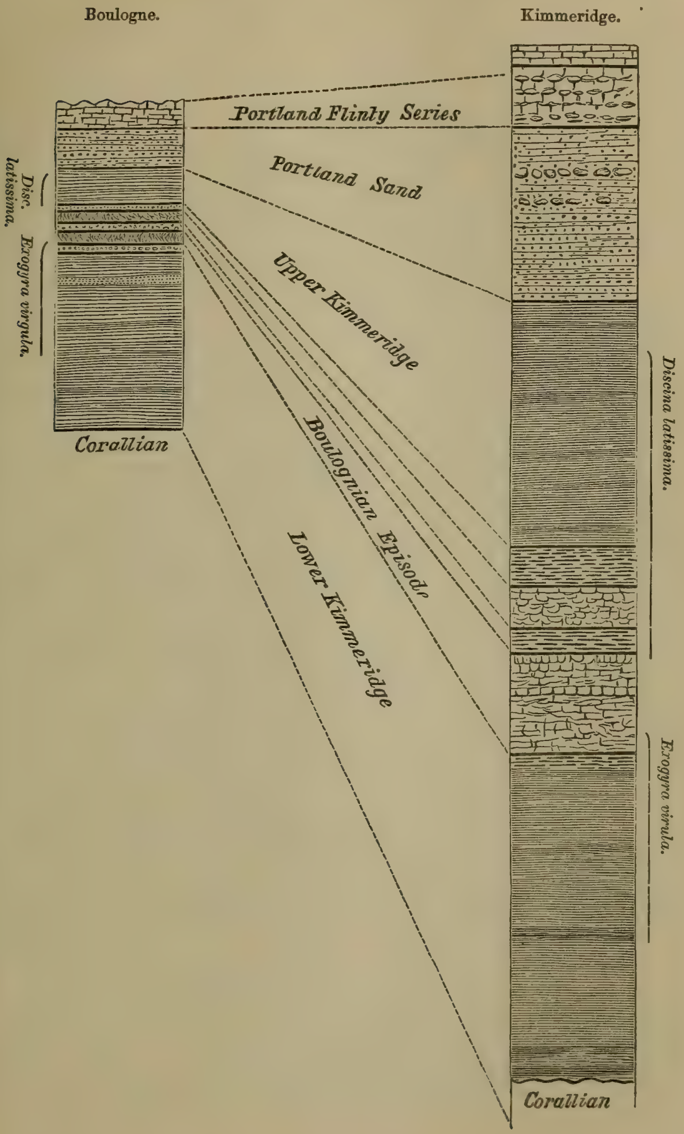
The description of this district would end here but for the fact of the French geologists introducing the terms Middle and Lower Portlandian, and asserting the latter to be absent from England. I have therefore reexamined the Kimmeridge Clay here in order to correlate it with the strata of Boulogne (see fig. 1). The measurements of the upper Kimmeridge have been checked, and it has been ascertained that the clays of Kimmeridge Bay are really lower than any to the east by their fauna and succession, and have a total thickness as actually seen of about 183 feet. They reach the anticlinal at the western end of the bay, and then dip rapidly down and towards the land in the direction of Worborrow. In the lowest 28 feet of shales I have found *Ammonites alternans* associated with *Exogyra virgula* and *Am. biplex*. We are therefore fairly in the Lower Kimmeridge, but not at its base; and we learn that all the series is here more or less shaly, as it was in the sub-Wealden boring. Now if we add all these ascertained measures together, we find just 1100 feet between the base of the Portland Stone and the lowest part of the Kimmeridge Clay visible, which is not, however, its base. It seems absurd to suppose that with this enormous thickness any part of the series should be absent, and that such member should be found at Boulogne, where the total thickness between the Portland and Corallian is less than 450 feet. We should rather expect that any division found at the latter place would be expanded to twice its amount; and it is with such an idea that we must seek out equivalents. The fact is that in England we possess the *normal* formation, to which the name Kimmeridge was originally applied; while at Boulogne we find an *episode* having no relation to the Portlandian above, but to which the name of "Boulognian" may well be given. The episodal character may be easily seen in the cliffs on either side of the town, where conglomerates are found, and an actual dying off beneath the Fort du Mont de Couple.

It is beyond the scope of the present paper to notice the succession here any further than it may throw light on our English equivalents. The upper part of their "Middle Portlandian" is our Portland Sand; as M. Pellat states, it is more sandy than the shales below, and has the aspect of the St.-Alban's beds with their small nodules; it contains such leading fossils as *Mytilus autissiodorensis*, *Pecten Morini*, *Avicula octavia*, *Astarte scalaria*, *Lima boloniensis*, *Perna Bouchardi*, *Pecten lamellosus*, *Astarte Sæmanni*. This amounts to 57 feet, which is not a quarter of the corresponding beds at St. Alban's. The lower part of their "Middle Portlandian" consists of soft sandy marls and shales, with cement-stone bands, not at all unlike the top of the Kimmeridge at Chapman's Pool. The *Cardium morinicum* (or, as I previously called it, *C. striatulum*), *Belemnites Souichii*, and *Discina latissima* serve to prove the identity.

Referring to my section on the Kimmeridge coast*, in Nos. 1 to 9 I have traced three bands of fossils. No. 5 contains abundance of *Dentalium Quenstedti*, apparently not yet found at Boulogne. No. 7 has a species of *Alaria*, perhaps *A. cingulata* (Koch & Dunk.), which occurs also in the Lower Kimmeridge; and No. 9 is full of *Discina latissima*. These last two occur in the same order at Boulogne; but the comparative thicknesses of the deposits are 252 feet in England and in France 44 feet. We are thus forced to look for the normal representatives of the Boulognian episode in the beds from No. 10 downwards of my section. The place of occurrence of this episode is not so far removed but that we may hope to trace some mark of its occurrence at Kimmeridge; but the fossils, being mostly "co-variants," will yield us little assistance. The general character of the deposits at Boulogne is as follows:—There are three more ferru-

* Quart. Journ. Geol. Soc. vol. xxxi. p. 198.

Fig. 1.—*Comparative Sections at Kimmeridge and Boulogne.*
(Scale 250 feet to 1 inch.)



ginous and sandy masses, of which the two lower are conglomerates, and the intervening beds are more marly and tend to run into cement-stone. Although these alone have been called "Lower Portlandian," some 55 feet lower down another group of sand and sandstones is met with. A somewhat similar grouping, on a much larger scale, is seen in the section between Emmets Hill and Hen Cliff. My Nos. 10 to 12 are a peculiarly laminated sandy series, which I called "paper slab." Following this is a group of cement-stones and dicy clay, Nos. 13 to 19. Then there is a very solid paper slab, followed by papery shales, to correspond to the upper conglomerates, including Nos. 20 to 22. The more mixed material, including a cement-stone, occupies Nos. 23 to 28, and then the representative of the lower Boulogne conglomerate is a massive rock, No. 29, below which, indeed, are other more sandy beds at some distance, which may correspond to those in the Kimmeridge Clay at Boulogne.

The beds thus reckoned in England amount to 244 feet as against 40 feet at La Crèche and 50 feet at Portel, which is not far removed from the proportional increase proved in the overlying beds. But we are not without aid from the fossils. It is very remarkable that *Exogyra virgula* occurs in thousands beneath the so-called "Lower Portlandian," and it extends upwards to the base of the clays overlying the lower conglomerate, where it forms almost a lumachelle; yet it dies out suddenly. Other small oysters become abundant, and even form beds; but they take the place of *E. virgula*, which is nowhere to be seen. In the Kimmeridge cliffs I searched diligently each bed from No. 10 downwards to find out at what horizon this characteristic oyster is first met with. Nowhere could I find it till I reached No. 28, where it is fairly abundant; and this bed occupies *exactly* the position where it is first seen in Boulogne, according to the above correlation. The whole series is, unfortunately, but feebly fossiliferous; the most abundant fossil is an Ammonite, which, I think, from its adult characters, must be *A. suprajurensis*. If this be so, it is another proof of the correlation.

I hold it therefore proved, by as good proofs as can be had under any similar circumstances, that the Boulognian episode is of the age of the lower part of the Upper Kimmeridge—that its representatives are not absent from England, but they are not episodal in the typical district at least. In just the same way we have in England no Pterocerian episode as yet discovered, though the lower part of the Kimmeridge is continuous. The existence of this Boulognian episode has misled the French geologists, in spite of their claim to be guided solely by the fauna, to associate these beds with the Portland rocks, with which they have very little in common, their invariant fossils being those of the Kimmeridge Clay; and Dr. Fitton was right when he regarded them as an "accident" in that formation.

3. *Upway.*

The section at this place (fig. 3, Pl. VIII.) is small but instructive.

The topmost bed, No. 1, is a solid block, of a thickness of 3 feet 6 inches. The upper foot is a creamy limestone, not at all oolitic; the next foot is a shell-bed, full of *Trigoniæ*, but with no *Cerithium portlandicum*; and the rest is a suboolitic limestone with few shells. The identity of this with the uppermost three beds at Worth, which are there 19 feet thick, is very obvious. The upper portion is cited by Damon as belonging to the Purbeck, and quoted to show the amalgamation of the two deposits. I have seen no proof of its being Purbeck; and the corresponding bed at Worth is full of *Trigoniæ*.

No. 2 is chalk and flint, the latter in large masses, and most abundant towards the middle; the chalk, however, is good enough to burn for lime. The total thickness is about 40 feet. This is said to be succeeded by

No. 3, a hard clay. There can be as little doubt that No. 3 corresponds to the clay at Portland which underlies the flinty series to which No. 2 here corresponds. As this in the same way corresponds to No. 10 at St. Alban's, there must be 48 feet of rock, including the quarried stone at Worth that is here absent. We may regard this as a proof that the topmost beds, both here and at Worth, do represent the building-stones in different areas, and that the unconformity between them and the flinty series is a well-marked one. The smaller amount of siliceous material in this locality apparently encouraged vertebrates to frequent it, since the remains of *Pycnodus*, *Chimæra*, and Turtle were obtained at one visit. The ordinary fossils are those of the flinty series, e.g. *Cardium dissimile*, *Pecten lamellosus*, *Trigonia gibbosa*, *Lucina portlandica*, and *Ammonites boloniensis*.

I have not been able to visit Corton, where the Portland sand is said to be exposed and to yield Belemnites. In Ringstead Bay this part of the series is intermediate in development between that at Portland and that at St. Alban's. For the upper bed is 14 feet of the sandy cement-stone, the clay having died out; it is succeeded by a 3-feet lumachelle, as in Portland, and, finally, the hardened sandy marl *ad libitum*, containing the same undulate *Trigonia* as at Portland, and another like *T. gibbosa*.

The changes in the Portland series thus demonstrated in its typical locality prove its essentially episodal character. The two most constant portions are the lower part of the flinty bed and the sandy cement-stones.

4. *The Vale of Wardour.*

Although the common fossils and the whiteness of the limestone tell the geologist at once that the rocks of this district are Portland, he soon finds, on coming to details, that they require study before their relations to those of the typical district are made out. The succession of the beds must be traced in various quarries; but a general account will be given of the whole.

In the Museum of Practical Geology is a large block of stone from this district, in which the junction of the Purbeck and Portland is said to lie, the one half of the stone being of marine and the other of freshwater origin. I do not know on what evidence this rests: my own observations, possibly too brief for the purpose, did not reveal any such united stratum; nor do I read any proof of it in Fitton. But it induces me to give an account of the Purbeck beds seen in the great quarry of Chicksgrove overlying the Portland.

Section of Rocks above the Portland between Chilmark and Lealam.

	ft.	in.
a. White finely laminated limestone	3	0
b. Black "surface-soil," with many rounded pieces of limestone and silicified trunks of trees .... 1 foot 6 inches to	2	0
c. Creamy irregular limestone, in some places turning into a lighter "surface-soil" above, with larger pieces of limestone, in others having a vacuous limestone at the top	6	0
d. Calc-tuff passing into the above	1	4
e. Brownish coloured very clean-grained oolite without fossils, and with strong flints at the top in some places	0	8
f. Irregular botryoidal limestone, passing into a consolidated brash and sometimes chalcedonic	4	6
g. Brown clay with small *remaniés* fossils and shell-fragments	0	3

This does not agree exactly with Dr. Fitton's account. The details doubtless vary in different quarries. He alludes to a bed occupying the place of *b* as "a dirt bed," and remarks upon the flints of *e*; but he has not, apparently, seen *g* and the first few feet below it, as he states that "the freshwater strata here rest immediately upon a bed containing marine fossils without the intervention of any clay or dirt." Certainly none of the above strata contains marine fossils, while the bed immediately below *g* does. Hence I conclude that, whatever the appearances may have been in Dr. Fitton's time, a careful examination will always show that the Purbeck is divided from the Portland by a well-defined line. It would, indeed, be remarkable if it were otherwise, and the events which should make it so almost inconceivable. The Portland series, therefore, commences with

No. 1 (Pl. VIII. fig. 4). This is a fine-grained brown oolite, the grains having no intervening cement. It is a remarkable rock; and *e* is probably derived from the denudation of it in the neighbourhood. The lower part of this is shell-brash, full of empty casts of *Cerithium portlandicum* &c. This cannot be the junction-rock alluded to above, as the upper part of it could not well be proved to be of freshwater origin. Thickness 1 foot 8 inches.

No. 2. A thick mass of rock, finely oolitic at the top, where it contains *Cerithium portlandicum*, and becoming softer and changing to a fine shell-brash below. There are also vacuous bands here. It makes a magnificent white building-stone, very free and soft when first extracted, and rings under the hammer like a bell. The similarity of these two rocks to the Whit bed and Roach of Portland is almost too striking, as the latter are not in character even at Upway.

Nevertheless they occupy the same position in the series, and Nature must have repeated herself in independent areas. Unfortunately the thickness of this mass and its relations to the bed below cannot be accurately ascertained, as the junction is covered in the only quarry in which I have seen this part of the formation. It may be 16 feet.

No. 3. White chalk, like that of Upway, having abundance of flints, both in beds and in fissures, throughout the upper 14 feet, but none in the lower 12 feet. This is sufficiently pure to burn for lime; towards the base, however, it becomes harder and more shaly. It is remarkable for the abundance of its common Portland fossils, such as *Pecten lamellosus*, *Cardium dissimile*, *Lucina portlandica*, *Pleuromya tellina*, and *Ostrea expansa*. It has also many *Trigoniæ*, both *T. gibbosa* and clavellate ones, and a few rarer fossils.

No. 4 consists of two parts, which vary rapidly; the upper part is a solid block of about 2 feet to 4 feet, with few fossils except *Trigoniæ*; the lower is a softish limestone, crowded with fossils, and making up a total of 8 feet. This is one of the most fossiliferous beds of the formation; and the fossils are beautifully preserved as calcite. The most common is *Astarte rugosa*, every fragment containing it. Associated with this is *Cerithium concavum*, which appears really to differ from *C. portlandicum*, and to be found in this bed to the exclusion of the latter. There is also *C. Bouchardianum*, *Nerita transversa*, var. *minor*, with its colour-spots, and *Neritoma sinuosa* in great abundance.

No. 5 is a *Trigonia*-bed, scarcely separable from the beds below, and varying from zero to about 4 feet. The species is *T. gibbosa* as usual.

No. 6 is the great mass of stone for which all the quarries in the neighbourhood are worked. It is a fine freestone, more or less false-bedded, and consisting of great blocks in fairly thick beds, but in places somewhat concretionary. It is more of a sandstone than a limestone, though somewhat calcareous. Here and there in some quarries are thin bands of flint, in others bands of *Trigoniæ* preserved in chalcedony. According to Fitton, a similar chalcedonic band has yielded the *Isastræa oblonga*. Large *Ammonites boloniensis* are found here, and *A. biplex*. The total thickness of this has not been ascertained; the greatest amount seen is 17 feet; and this is certainly not far off the maximum.

No. 7. In one valley, about two miles W. of Tisbury, the stone No. 6 was traced down the slope by surface-fragments from the *Astarte rugosa*-bed at the top to an outstanding mass of a *Trigonia*-bed, which is thus proved to underlie the stone; but of its thickness or arrangement no particulars could be ascertained.

These form the only rocks which would by any one be referred to the Portland Stone. As far as No. 3 they agree fairly with the Upway beds, and so with part of the flinty series of Portland. The fossiliferous zone below is not met with in the same form to the south, though its most abundant fossils are found in Portland, and probably in the flinty series. The lower bed (No. 6), which is really the most important in this district, is a very distinct deposit, most like the lowest beds at St. Alban's; only the flints happen to be scarce. The prevailing Ammonites and the *Trigoniæ* at the base, and the occurrence of the coral permit of no separation palæontologically, and we are forced to regard this as a downward development of the Portland Stone. Yet it is lithologically a calcareous sandstone, and, if the cementing material be anywhere absent, actually a sand.

The succeeding rocks in this district have never been described, and they are with difficulty followed in fields and road-cuttings. The best section is seen in the road leading from the village of Hazelton to the railway, which, confirmed by others, gives us :—

No. 8. Yellow impure sand becoming marly at the base, often coloured brown by iron; thickness unknown, but cannot be much more than the maximum seen, viz. 12 feet. No fossils have been seen in it.

No. 9. Impure calcareous bed, rather rubbly, with large grains of Lydian stone or glauconite, 3 feet 6 inches. Blocks of rock of the same character strewn on the fields have yielded a remarkable fauna to a very short search, viz. *Trigonia Pellati*, *T. variegata*, *T. concentrica*, *T. Micheloti* (?), *Mytilus jurensis*, *Perna Bouchardi*, *Pecten concentricus* (?), *Astarte supracorallina* (?), *Exogyra bruntrutana*, and *Serpula* sp. Indications of some of these are seen also where the block is *in situ*.

No. 10. Harder bed of the same character, 3 feet 6 inches, with *Trigonia Pellati*, *Ostrea bruntrutana*, &c. In one spot, on the road from Tisbury to Wardour, this bed is alone seen; it only reaches 18 inches in thickness at most, and is scarcely continuous, but, as it were, in eroded blocks enveloped in the sand above, which is here not so argillaceous.

No. 11. A yellowish-grey uncompacted calcareous stone, with no fossils seen; its base is not traceable; but at a depth of 21 feet from its top the springs break out. These measures are checked by the fact that at the Tisbury station the stone No. 6 is worked in a quarry about 40 feet above the level of the railway, which is on Kimmeridge Clay; so that that thickness is an upper limit for the intervening beds.

The character and fossil contents of these beds are different from those of any other locality. The fossils indicate a period anterior to the usual Portland Sand; indeed they point to an episode similar to the Boulognian. The yellow and hence peroxidized ferruginous sand is very different from the blue sand of the coast sections, and may indicate a more superficial deposit. The diminution and erosion of the hard block No. 10 cannot be much relied on, as the section is not sufficiently removed from surface influences of a later date; but, on the whole evidence, it appears to me that we have here an area which was elevated previously to the period of the Portland Sand, received its calcareous and shelly accumulations, and then escaped the great deposits of sand which are so alike at Swindon and at Portland, but have here only a representative of a few feet. From the absence, however, of any intervening Kimmeridge Clay, it can scarcely be so old an episode as the Boulognian.

Devizes.

The exposure of Portland rocks in this neighbourhood, as marked by the Geological Survey, is a feeble one. It may, however, be considered as modelled on the Swindon type, though exposing only the lower beds. The topmost part of the Kimmeridge Clay is very sandy, and contains the usual Swindon and Hartwell fossils; the greyish-yellow sands overlie this; and above these, again, at Crookwood, are some fissile limestones, with *Pecten lamellosus* and *Trigonia gibbosa.*

Swindon.

The sections in this neighbourhood are the most extensive and interesting out of the islands of Portland and Purbeck; and yet, though the locality has been visited again and again, they really seem almost unknown, and the interpretations placed on the phenomena visible in the great quarries themselves are strangely contradictory.

The first point of interest is the relation of the Purbeck to the Portland. Dr. Fitton merely notices the presence of botryoidal limestone over the Portland. Mr. Brodie * describes the Purbeck beds only, proving their freshwater character by the contained fossils, and states most truly that "the surface of the Portland strata has been greatly denuded previously to the deposition of the overlying group; for in many cases the latter is deposited in hollows and cavities, where the Portland Sand has suffered erosion by water." On the other hand, Mr. Godwin-Austen † states that "with the dip of the beds south these disturbed bands of clays and sands are seen to be surmounted by layers of tranquilly deposited sandstones in thin layers, interstratified with sands, and in these the forms of the marine Portland reappear." No such sands and sandstones are recorded by any other observer; their precise supposed position is not indicated; the names of the marine shells are not given; and I have searched for any such in vain. On this statement the author founds the belief that "the Wealden (Purbeck) is not, as has hitherto been represented, a freshwater accumulation of an area of dry land subsequent to the oolitic period, but was contemporaneous with the Portland, and perhaps even with older portions of the oolitic series." This view is not confirmed by the officers of the Geological Survey in their memoir on this district; but in the report of the excursion of the Geologists' Association to Swindon in 1876 under the guidance of Mr. Moore ‡ it is stated that above a "so-called Purbeck bed," "the regular Portland limestone comes on again rich in casts of the usual Portlandian shells, showing most clearly how 'Purbeck' and 'Portland' conditions, inosculated at this spot, and that . . . . we actually have the Portlandian overlying the Purbeck on the east

* Quart. Journ. Geol. Soc. vol. iii. p. 53. † *Ibid.* vol. vi. p. 466.
‡ Proc. Geol. Assoc. vol. iv. p. 548.

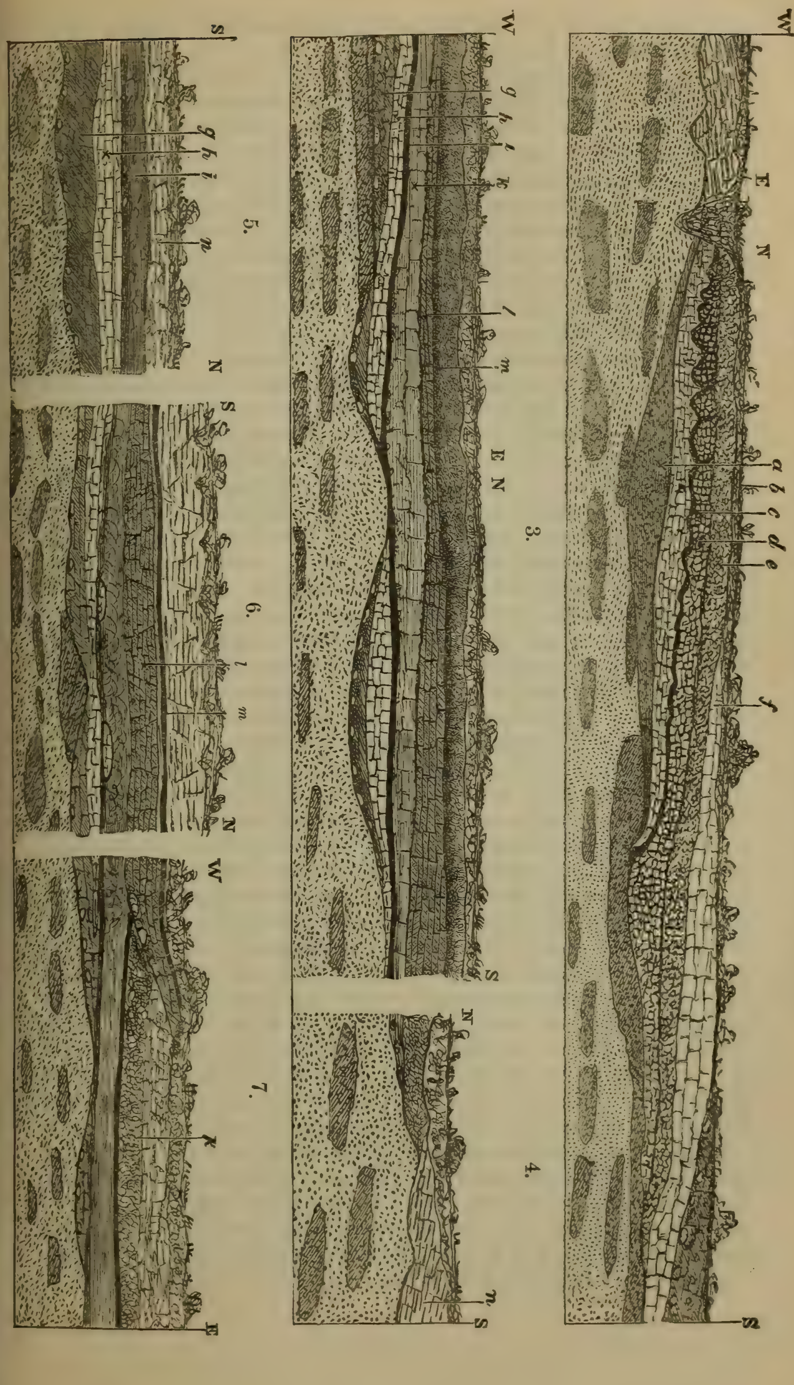
side of the great quarry at Swindon." It is obvious that a quarry that can give rise to such ideas must show a very remarkable section; and in fact a more complicated and at the same time instructive *series* of sections I have never seen. The whole result of their study, however, is, distinctly to negative the idea of any intermixture of formations, and to show that the one is unconformable to the other.

I have carefully traced every bed through every part of the quarry, and have examined each for fossils, so far as to settle the question of the marine or fluviatile origin of the beds; and I now present a continuous section (figs. 2–7, p. 205) which will, I believe, demonstrate the truth of the idea of unconformability.

The particular section which really shows a very peculiar development of true Portland rocks beneath the Purbeck is in the N.E. corner (fig. 2); it will therefore be best to begin at that point and trace the beds either way.

The northern face of this quarry shows an eroded surface of the main Portland rocks of the district, which for the sake of distinction may be called for the present the basal sands. In the hollows of this surface and for a few feet above are some flaggy limestones, the relations of which to the deposits succeeding to the south are obscured by a "pot-hole," but which appear to belong to a set which overlie all the other beds in these quarries. No fossils have been discovered in these flags. The eastern face shows also an eroded surface, but a more regular one; and lying on it is (*a*) a lenticular mass of brownish earthy sand; it is of very limited extent, as it may be traced in less than a hundred yards from its commencement to its close, and is never more than 4 feet thick. It contains black carbonaceous patches; and hardened parts of it have *Trigonia gibbosa*, *Cerithium portlandicum*, and *Lucina* in them. A tooth of *Goniopholis* and freshwater shells have been reported from here. Upon this is (*b*) a white creamy limestone of more uniform thickness, but of no greater horizontal extension. It has an even surface below, but above is festooned by the encroachment of the succeeding beds before its consolidation. This contains *Turritella* (cf. *minuta*, Koch & Dunker), and a little Gasteropod like a smooth *Turbo*, but which has not sufficient character for naming. In some places it also contains abundance of *Cerithium portlandicum*. The next deposit (*c*) is a dark earthy clay, at first sight like the material of a "dirt bed;" but both this and *a* are distinguished from the somewhat similar overlying beds by the absence of any rolled stones. The dark clay is no more extraordinary than similar deposits in the Chalk. The termination of these three takes place together at the same spot, where they are all rounded off between the succeeding deposit and the basal sands, as in the figure. Overlying this, and forcing it to take up its irregular shape, is (*d*) a shell limestone composed of *Cerithium portlandicum* and *Astarte rugosa*, with more occasionally *Trigonia gibbosa*, *Pecten lamellosus*, *Cardium dissimile*, *Neritoma sinuosa*, *Buccinum angulatum*, and *Corbicella Morœana*. These have collected in hardened blocks, which sank into the soft

Figs. 2-7.—*Relations of the Purbeck and Portland Rocks at Swindon.*



Figs. 2-4. The Eastern face. Figs. 5-7. The Western and Northern faces.

mud below or became agglutinated to the basal sands when *a* and *c* had died out.

This passes up into (*e*) a bed which below is a calc-tuff, but which gradually changes through a fine-grained broken-shell limestone into a fine white unfossiliferous limestone, and continues in an irregular manner into (*f*) a rather thick-bedded limestone. These three have a maximum united thickness of about 12 feet. They die out one after another against the basal sands, whose upper part has hereabouts a more continuous hardened block. The termination of *f* is not seen; but the end of the others may be traced in the interval between the two quarries. In the next quarry to the south, however, the top block of the basal sands has again 6 inches of stone full of *Cerithium portlandicum* surmounting it, showing that *d* is discontinuous by erosion and not by lack of deposit. The beds thus enumerated are nowhere else seen in the quarries; but the Purbecks which overlie the basal sands on the western side may all be identified with those that are to follow. The first of these (*g*, fig. 3) is a light limestone brash, 6 feet in thickness where first seen, but rapidly diminishing to zero. Incorporated in it are various stones derived from the three lower beds, containing, of course, the fossils of the beds from which they are derived; but there are sandy masses as well, so as to leave no doubt of the *remanié* nature of the stones; towards the top this bed becomes more compact. Further on in the same quarry-face are two shallow erosions such as might be made by a winding river; and they are half filled by deposits similar to *g*, dying out on their sides. These are darker-coloured at the base, and contain very obvious stones. The compact upper portion (*h*) is continuous into the first hollow, and is then cut off, but occurs again in the next hollow; it attains a maximum of 2 feet, when it becomes quite a creamy limestone and yields small *Paludinæ*. Above this comes (*i*) a dark line of earth which becomes black towards the east, and contains many little white stones, as if it were a "dirt bed" or vegetable mould. This passes into (*k*) a limestone brash, which yielded me a crocodilian scute. These two beds commence at one end of the quarry at 1 foot, increasing to 4 feet, and then die away to 2½ feet. Above comes (*l*) some thin-bedded ferruginous-looking stone, which gradually thickens: the base is still more ferruginous and solid; but I have not seen any fossils in it. The topmost deposit (*m*) beneath what may be an overwash of any age, though distinct from the modern soil, is another dark earthy band similar to *i* or the base of *g*. All these numerous beds die out shortly to the south, though the manner of their disappearance is not visible; for in the next quarry (fig. 4) we find nothing but the flaggy beds of the first, N.E., pit overlying the basal sands.

Having thus followed the several beds along the eastern side, we are able to understand better the appearance presented by the western face of the greater quarries (figs. 5–7). None of the deposits from *a* to *f* can be recognized; but the basal sands present an undulating surface, on which lies a brownish calcareous earth with stones of various sizes along the bottom, and attaining a maximum of 3 feet. This reminds us at once of *g*, especially as seen in the last erosion, and is no doubt its continuation; for upon it we find a creamy limestone similar to *h*, whose thickening in one direction and dying-out in the other may here be traced. This, again, is followed by the representatives of the earth and the brashy limestone *i* and *k*, here full of Cyprids. The blocks at the base are, in one or two cases, of large size, containing *Cerithium portlandicum*; and there are rolled fragments of Kimmeridge (?) Clay; but usually they are only small white stones, and the limestone becomes compact towards the top. The thin-splitting ferruginous rock follows for about 1 foot; and then succeeds a line of laminated dark earth between two lighter bands; and over all comes 3 or 4 feet of flaggy limestone, which may be, but is not proved to be, the same that overlies the basal sands at the north and south extremities of the eastern section. But the extraordinary series of local deposits is not yet exhausted; for the ferruginous beds (*l*) which disappear to the south, when traced northward come to a bank, against which they end, and have derived blocks on the slope at their base. This bank is formed by first another dark clay band like *i*, and then by *k*, a mass which is rubbly towards the base, but calcareous towards the top, and has a limestone band in the middle. All here is covered by the dark sandy soil referred to the Lower Greensand.

We have now to determine where among these deposits the Portland rocks end, and thereby to learn the nature and circumstances of formation of the upper beds of that series. The section given in the Geological-Survey Memoir of the N.E. quarry shows that, while *d* and *e* are considered Portland, *f* is considered Purbeck. That of the western side makes *i*, or *l*, or *m* the first Purbeck bed, according to the part of the quarry it is supposed to be taken from; while *h* is said to contain *Trigoniæ*, and the *f* on this side is called Portland Limestone, because of the nodular fossiliferous masses it contains. Mr. Brodie's section, however, makes *h* contain *Planorbis*, and reckons it as Purbeck. I certainly saw no *Trigoniæ* in *h*, nor any thing but impressions of small shells, except on the east side, where the *Paludinæ* occur. I could find no freshwater fossils in *f*; but its general behaviour, lying in hollows, and being filled at its base with derived Portland blocks and small stones, proves its unconformity to the Portland, and that it was deposited under circumstances that are only to be found in the Purbeck. On the other hand, *d* is undoubtedly Portland by its fossils; and, as a matter of fact, all the fossils found in the actual beds above *g* are freshwater, all those of the beds below *d* are marine. As for *e* and *f*, they attach themselves to *d* both actually and in their range; and yet *e* is a calc-tuff, like the usual base of the Purbeck, and both appear to be unfossiliferous. Their character, therefore, at present is doubtful, and we must draw the upper line of the Portland either above *f* or above *d*; in the latter case it would certainly be easy to obtain a block of which the upper part would be Purbeck and the lower Portland. This inclines me to include the two in the latter.

In the general section of Swindon (see Pl. VIII. fig. 5) we may therefore include all the deposits from *a* to *f*, as:—

No. 1. This is shown to be exceeding local in range, and different in character from any other Portland rock; but its origin cannot be satisfactorily discussed until after the description of the succeeding beds.

No. 2, hitherto called the "basal sands," have much of that character; but even when most sandy they are still calcareous, and in parts consist of comminuted shells. There are many irregular, hardened, calcareous blocks, and some lines crowded by *Trigonia gibbosa* of many varieties and other shells, especially about 9 ft. from the base. A good deal of it is false-bedded; and the blocks often lie parallel to the false dip, and not to the true. It is of uneven thickness, owing to erosion at the top; the maximum measurement is 27 ft. It would be impossible for any one who, like Dr. Fitton, had examined the Portland series in other districts to mistake the nature of these rocks. They are the obvious equivalents of the Tisbury stone and the lower portion of the flinty series at Portland. Here they have a minimum of consolidating silica, at Portland a maximum. They are accordingly so described by him; and in this he is followed by Godwin-Austen and Damon. But, for some reason (nowhere stated), the Geological Survey has called these beds Portland Sands, and coloured them so on the map; and hence they have been in late years so considered. This has led to further errors and to an unfortunate overlooking of the true Portland Sand in this district. The principal fossils of these calcareous sands (besides the usual *Trigonia*, *Perna*, &c.) are *Ostrea solitaria*, *Lima rustica*, *Mytilus unguiculatus*, *Cyprina pulchella*, *Corbula dammariensis*, and *Pleuromya tellina*; but they are not common.

No. 3. The beds which follow these in the quarry, and which appear to have been seen only by Mr. Godwin-Austen, are of considerable interest. They are very fossiliferous, and present a greater development than the corresponding beds at Tisbury and Portland. They are only seen in the deepest parts of the great quarry—at the present time towards the south-west end. Here are 7 ft. of rubbly limestone-rock full of *Trigonia gibbosa*, the middle part entirely made of them. This is used for roads only; but the lowest part is said to be burnt for lime. At its base is a great accumulation of Lydian stones, or grains of glauconite. These subdivisions do not seem very constant in character, nor the shells always the same; for the section given by Mr. Godwin-Austen of the opposite (N.E.) corner is somewhat different in detail. Fortunately, however, these beds have a wider range and some economic value, and hence are quarried at several places in the neighbourhood. The nearest to Swindon is that, long known, on the north of the road to Coate. Here are two sections succeeding one another on the dip, which is to the south. In the first, nearest the road, only the ordinary sandy beds, with their great indurated blocks (as in the great quarry), are to be seen; but in the second, succeeding these in perfectly clear sequence, are the following:—

Section north of the Road to Coate.

	ft.	in.
a. Calcareous sands, with hard block (as in great quarry)	8	0
b. *Cardium-* and *Trigonia*-bed	3	8
c. White chalky rock, with *Cardia*	1	2
d. Limestone brash, with *Trigoniæ*	2	6
e. Glauconitic limestone, in two beds	2	0

There cannot be the slightest doubt, then, that these beds succeed those of the great quarry in a downward direction. The supposition that they corresponded to the beds overlying the "basal sands" has led to the introduction upon the map, at this spot, of a fault which does not exist. This quarry forms part of a slight synclinal fold; for on the other side of the road is another, in which the beds dip to the north. This shows the same succession—the "basal sands" at the top and the remainder of the beds below, the last becoming very argillaceous. There is some doubt whether the glauconitic bed ought not to be separated from the rest, though it doubtless corresponds to the base of No. 3 at Swindon. These quarries show a very interesting fauna, as in the following list:—

Fossils of the Trigonia-*beds near Swindon.*

c. Ammonites boloniensis (*De L.*).
—— pectinatus (*Ph.*).
—— Boisdini (*De Lor.*).
Pleurotomaria rugata (*Ben.*).
Natica elegans (*Sow.*).
c. Trigonia gibbosa (*Sow.*).
—— Voltzii (*Ag.*).
—— incurva (*Ben.*).
(in *e*) —— Carrei (*Mun. Chal.*).
(in *c*) Cyprina elongata (*Blake*).
Cypricardia costifera (*Blake*).
Anisocardia pulchella (*DeLor.*).
c. Cardium dissimile (*Sow.*).
Lucina portlandica (*Sow.*).
c. Pleuromya tellina (*Voltz*).
Thracia tenera (*Ag.*).
Mytilus unguiculatus (*Phill.*).
—— boloniensis (*De Lor.*).
—— pernoides (*Röm.*).
Lima rustica (*Sow.*).
—— ornata (*Buv.*).
Pecten lamellosus (*Sow.*).

The quarry to the east of the reservoir reaches to the upper part of these beds, having No. 2 overlying. It is characterized by the abundance of *Ammonites*, *Pecten*, and *Pleuromya*, as above.

The outlier at Bourton (Pl. VIII. fig. 6) shows, for the most part, a continuation of these beds. In the southern quarry little but loose sandy limestones, with very few fossils, are seen. These no doubt correspond to the "basal sands" of Swindon. The only fossil actually seen was *Trigonia gibbosa*; but both this and Ammonites become more abundant towards the top. In another quarry in the village, the succeeding rubbly beds are full of various fossils—*Pleurotomaria rugata*, *Pecten lamellosus*, *Trigonia gibbosa*, *Cardium Pellati*, *Cyprina swindonensis*, &c. The most noteworthy feature is the abundance of *Echinobrissus Brodiei*, which, like all other Portlandian urchins, is elsewhere so rare. The *Cardium*, recorded also by M. Sæmann from Swindon, and compared by M. De Loriol, is distinctly different from *C. dissimile*, and belongs to the lowest true Portland beds at Boulogne; and the *Cyprina* is found at a lower horizon at Swindon. Besides these are many Ammonites not seen *in situ*—*A. boloniensis*, *A. biplex*, and a curious form not seen elsewhere,—perhaps the *A. Bleicheri* of Boulogne. These beds have a thickness of some 8 ft.; and they are succeeded by a strong solid block 3 ft. thick, for which the quarry is worked. This contains few or no *Trigoniæ*, but is full of *Perna Bouchardi* and oysters. Its base is full of dark-coloured stones of various materials and sizes. Among them are Lydian stones and light-coloured quartz; but some are hardened phosphatic nodules derived from fossils of previous formations, among which a *Cardium* and a *Pleuromya* are recognizable, doubtless from some part of the Kimmeridge Clay. The inference to be drawn from these nodules must not be overlooked. Glauconitic grains, derived doubtless in the same manner, are usually characteristic of the sand below; and similar nodules occur in the lower beds at Tisbury; but all are absent in the district of Portland. Hence these more northern districts were more rapidly upheaved than those to the south, and brought earlier into the conditions which are necessary for calcareous deposits. Below this hardened block comes a mass of argillaceous shell-conglomerate, like No. 5 of Swindon, to be noticed hereafter. All these features indicate that the fossiliferous Bourton beds, though of a similar structure to the *Trigonia*-beds at Swindon, represent a slightly earlier date as well as that at which the latter were formed. These, therefore, are the earliest rocks which in this district can be referred to the Portland Stone, and are parallel to the *Trigonia*-bed at the base of the Tisbury freestone.

The similarity of the succession noticed in the various districts as yet described shows that the order of events was the same, but affords no proof that they were synchronous; the evidence of the fossils, on the contrary, goes to show that the more northern were the earlier; and this we must bear in mind in interpreting the higher beds.

The "basal sands" of Swindon have been seen to be covered with shelly masses abounding in *Astarte rugosa*, just as the freestone of Chicksgrove is. These masses have other fossils in common; but the *Cerithium* is not *concavum*, but *portlandicum*, and therefore ceases to be a guide, and we must take the base of the chalky beds of Chicksgrove and Upway as the anterior limit for the age of No. 1 here. If the Purbeck be always of the same age, the posterior limit would be the age of the Roach; and thus the few small beds, limited to the N.E. of the Swindon quarry, would represent a long interval of time—*too* long for their obviously rapid deposition. No doubt there may have been *Cerithium*-beds overlying *f* (if that be truly Portland), of which the blocks in *g* are the only remnant; but there is no proof of this. Moreover we must not forget the difference in character between the Purbecks of Swindon and those of more southern districts. In the latter we have uniform deposits over considerable distances, lying on unevenly but not deeply eroded Portland rocks; in the former there are the carvings of rivers, the transported blocks, and the rapid dying-out of deposits—all features characteristic of subaerial action. Seeing, then, that we have reason to believe that the earliest "Portland Stone" here antedated that at Portland, we are justified in concluding that the land here emerged sooner from the ocean, and, moreover, more rapidly; hence the regular deposits reached only to the "basal sands." Then incursions from the land produced the strange *mêlée* of the beds *a* to *d*, as suggested by Mr. Godwin-Austen; and finally the newly risen Portland was carved out by the river whose course is still marked in the quarry. The more gradual elevation of the south left time for the deposition of the Whit bed and the Roach; and when the sea was finally expelled its place was taken by a large shallow lake, ofttimes dried up, and during portions of the minor oscillations supporting forests of cycads and conifers, whose growth on the spot, well known there, is sought for in vain at Swindon. We are led, therefore, to this apparently strange conclusion, that *the freshwater strata of Swindon, though unconformable to those below, and representing the Purbeck in the order of events, are probably in point of actual time as old as some parts of the Portland.* This conclusion will be found confirmed by a study of the districts further north.

No. 4. Below the limestones at Swindon, and for some way round, is a very stiff clay, which rapidly breaks down on exposure to the weather. It is very retentive of water, and makes a base for the wells of the town and for the reservoir to the south. I have seen it in several places; but in only one, a newly-made well in the town, were any fossils obtainable. These were *Trigonia incurva* or *Pellati*, *Perna Bouchardi*, *Mytilus autissiodorensis*, *Corbula dammariensis*, *Arca Beaugrandi*, and *Cyprina elongata*—a fauna which decides their correlation with the Portland Sand. I have not seen the true thickness; but it was reported to me as 20 feet, which must be a maximum. It will be remembered that just such a clay precedes the shelly limestones in the Isle of Portland. This clay, at Swindon, has unfortunately been mistaken for the Kimmeridge Clay, which has had the effect, first, of inducing the reference of the rocks above to the Portland Sands, and, secondly, of causing a neglect of the underlying beds. It was to the latter that Dr. Fitton alluded when he wrote of the Portland Sands, though they appear to have been not well exposed in his time.

No. 5. This bed is so well exposed in road-sections to the north and west of the Swindon hill, and contains so interesting a fauna, that it is extraordinary that it should have attracted so little attention. As seen in the great road-cutting on the north slope of the town, its upper part is a sandy glauconitic clay, full of fossils, and the lower part is a regular lumachelle of *Exogyra bruntrutana*. The total thickness is not here seen, but it must be more than 6 feet. On the western slope of the hill there is another road-exposure of these and the beds below. Here the present portion is a sharp ferruginous sandstone of brown colour, very irregular in its manner of lying, as though near its termination. It occupies, however, the same position, and must be a modification of the other form; Dr. Fitton alludes to a third form of it. The fossils also are somewhat different, and the oysters scarcely make a lumachelle. These beds have not been half searched; they would yield a very large fauna. A few hours on different occasions have produced the following:—

Fossils of the Portland Sand, Swindon.

Ammonites biplex (*Sow.*).
c. —— pectinatus (*Ph.*).
Alaria Thurmanni (*Cont.*).
Cerithium Lamberti (*De Lor.*).
c. Turbo Foucardi (*Cott.*).
Delphinula globosa (*Buv.*).
Pleuromya Voltzii (*Ag.*).
Plectomya rugosa (*Röm.*).
c. Pholadomya tumida (*Ag.*).
Sowerbya longior (*Blake*).
c. Astarte polymorpha (*Cont.*).
* —— Sæmanni (*De Lor.*).
Myoconcha portlandica (*Blake*).
—— Sæmanni (*Dollf.*).
Cyprina swindonensis (*Blake*).
—— pulchella (*De Lor.*).
Lithodomus, sp.
Lucina fragosa (*De Lor.*).
Cardium Morinicum (*De Lor.*).
c. Trigonia Pellati (*De Lor.*).
—— swindonensis (*Blake*).
Arca velledæ (*De Lor.*).
Mytilus autissiodorensis (*Cott.*).
—— longævus (*Cont.*).
—— boloniensis (*De Lor.*).
Perna Bayani? (*De Lor.*).
c. —— Bouchardi (*Opp.*).
Pinna suprajurensis (*D'Orb.*).
Lima boloniensis (*De Lor.*).
c. Pecten Morini (*De Lor.*).
—— suprajurensis (*D'Orb.*).
—— solidus (*Röm.*).
Placunopsis Lycetti (*De Lor.*).
Ostrea bononiæ (*De Lor.*)?
—— multiformis (*Koch & Dunk.*).
Exogyra bruntrutana (*Thurm.*).
* Acrosalenia Kœnigi (*Desm.*).

More, perhaps, of these are new than the list would indicate; but whatever names are assigned, the fauna itself is very distinct from that of the Portland rock. *Trigonia gibbosa* has not yet arrived, nor even *Cardium dissimile.* Many of the forms are characteristic of the so-called middle Portland of Boulogne or of the highest "Portlandian" beds of other districts. Indeed the relations are closer to the Kimmeridge Clay than to the Portland Stone; yet the stone most certainly belongs to the Portland Sand, and corresponds to Nos. 11, 12 of the typical section, with which it shows a wonderfully close agreement. At Bourton the bed beneath the conglomeratic rock is just like the top of this at the north of Swindon, and contains *Pecten Morini* and *Pholadomya tumida.*

Up to the present day there has scarcely been known a particular fauna for the Portland Sand. It has not been separated palæontologically from the Stone; and the fossils quoted from it are often those of the basal bed of the latter. In Dr. Fitton's list, which is still the longest, the only named species which do not also occur in the Stone, are two *Serpulæ*, a *Lima*, *Trigonellites*, and *Ostrea solitaria.* In Prof. Phillips's list *Hemicidaris Davidsoni* is the only one; but, in reality, many of his additions belong, in all probability, to this horizon, though quoted as from the Stone. Such, for example, must be his *Pecten nitescens* (=*P. solidus*), *Pinna lanceolata* (=*P. suprajurensis*), *Modiola pectinata* (=*Myt. autissiodorensis*), *Pholadomya rustica* and *inæqualis* (=*P. tumida*), and *Ammonites pectinatus* (which is the same as *A. Devillei*, De Lor.; but Phillips's name has the priority). The present list, with those that occur in Dorsetshire, will, to a certain extent, supply the deficiency.

No. 6. A series of loose yellow-grey or white sands, with enormous doggers, some at the top being a compact calc-grit, with *Trigonia Pellati* and *Pleuromya Voltzii,* some nearer the bottom being glauconitic and more fossiliferous, with *Pernæ* also. Below these

* Found by Mr. Hudleston.

the sand becomes much more argillaceous, but is not retentive of water, which bursts out above some sandy-clay beds crowded with the usual fossils of the Kimmeridge Clay. The line between the two formations is, perhaps, somewhat arbitrary; but the porous or non-porous nature is of some consequence, and the fossils suddenly cease above the water, except in the doggers. This latter fact is of no consequence palæontologically, as it may simply prove that the percolating waters have removed the fossils; but it adds to the proof of the lithological change. Including all this, the total thickness at the north of Swindon may be estimated at 50 feet, which is probably not *beyond* the truth. Mr. Godwin-Austen's section at Bourton makes this only 7 feet with a query. I did not see it there; it may have thinned in that direction, but scarcely to so great an extent.

I must here confess that I was in error about the Kimmeridge Clay at Swindon being all Lower Kimmeridge. The sandy beds at the top belong to the Upper by their fossils; those belonging to it are such of the list on p. 211 (Q. J. G. S. vol. xxxi.) as occur in the general list with W. only against them. The same may be said of the clay at Hartwell; it is Upper Kimmeridge; the fossils recorded *l. c.* p. 212, only prove its *relation* to the Lower Kimmeridge. The range of these sandy beds, and the fossils here and elsewhere found in them, prove them to correspond to the strata *above* the first paper slab of the typical section. This error was corrected by the perusal of M. Sæmann's statements. Unfortunately, from their misnaming these beds Portlandian, I had not read MM. De Loriol and Pellat's work, in which these statements are made. A further examination of the beds, however, has made me fully concur in them.

Oxfordshire.

In this county there is no place where the whole of the Portlandian rocks can be seen in one section, and no special feature is presented by those that are visible; hence the chief importance here is the means of connexion afforded between the counties of Wilts and Bucks. The various members of the formation dip gently to the east, and are overlapped unconformably by the ferruginous sands of a later period; so that one has to traverse miles in order to pass through a comparatively small thickness, and we must wait for the interpretation of the sections till Buckinghamshire has been examined.

The uppermost beds of the Portland here shown spread out in a broad area by the villages of Great Hazeley and Great Milton. The section at the former place has been admirably described by Dr. Fitton, who saw a lower bed of stone than is now visible; and I need only point out the general characteristics for the sake of comparison. The base of all these quarries (Pl. VIII. fig. 7) is a yellow sand (4), not in the least glauconitic, which extends downwards some 10 or 12 feet. In this must be contained the lower bed of stone mentioned by Dr. Fitton. The lowest stone (3) now seen is a shell-brash limestone, mostly devoid of fossils, least compacted at the top, but hardening below by an accumulation of shells, so that at the base it is full of *Trigonia gibbosa* and other fossils. This varies in thickness in the quarries from 5 feet to 8 feet, but is always the object of the excavations. It is separated from the overlying rocks by a thin band of clay, still full of broken *Trigoniæ*, which, in an ill-preserved state, abound throughout all the sections where any fossils occur at all, and especially towards the base. The next bed (2) is similar to the one below, but has the appearance of rolled masses of stone, so consolidated by similar material, that the separate pieces are scarcely recognizable, the whole being from 4 feet to 5 feet thick. The top (1) is a solid block of gritty limestone, 2 feet thick, with *Pernæ*. The chief fossils lie here in beds Nos. 2 and 3. The upper one contains, among others, *Cerithium portlandicum*; and the lower one has *Trigonia incurva*, *Lima rustica*, *Pecten lamellosus*, *Ostrea expansa*, and *Pleuromya tellina*. The presence of the last two is worthy of note. A similar section may be seen at Cuddesdon, where the roadway of the village is for some space made by No. 2. But it is difficult to find in this district any exposure of the lower beds. Pits are opened and closed again so rapidly that it is a chance at any moment whether any are visible. There is a road-section to the west of Great Milton, which might well commence at the base of No. 4; but its indications are not very satisfactory. It would show that there is a rubbly limestone (5) with *Pleuromya* and *Cardium* (? *dissimile*), which is very argillaceous towards the centre, and is followed below by nodular sand (6). The thicknesses, which are not great, cannot be accurately ascertained. Glimpses may be caught of a similar succession at Cuddesdon and Garsington. At the former, dark rubbly beds with green grains and small pebbles form the upper boundary of a pond, so that they are probably preceded by clay; and at the latter a temporary excavation showed 4 feet of rubbly green glauconitic beds full of fossils, in which *Cardium Pellati*, *Trigonia incurva*?, and *Ammonites biplex* abounded, but *Trigonia gibbosa* was very rare. This became very soft and green towards the base, with a number of small stones. Not more than 30 feet intervene between this and the Kimmeridge Clay, which, all over this district, is of the same sandy character at the top as it is at Swindon.

We are now able to place in its proper position the well-known section at Shotover given by Fitton *, Phillips †, and Sæmann ‡. This gives, as the latter author has shown, a bank with fossils, including *Trigonia gibbosa* at the top, and doubtless the home of many of the fossils quoted by Phillips. This corresponds to No. 5, and is succeeded downwards by non-glauconitic non-fossiliferous sands, and then sands which are both glauconitic and fossiliferous and contain the huge doggers, as at Swindon. The total thickness seen here is estimated by Prof. Phillips at from 70 to 80 feet. There can be no mistaking these sands, with their glauconitic grains and fossils such

* *Loc. cit.* p. 278. † Geology of Oxford, p. 413 and pl. 16.

‡ De Loriol and Pellat, Mém. Ac. Soc. Phys. et Hist. Nat. Genève, tom. xix. p. 192, pl. i.

as *Pholadomya tumida* (*rustica*, Ph.). They are the strict representatives, not as Prof. Phillips seems to have thought, of the "basal sands" of Swindon, but of No. 6 of that station, the great series of sands which lie beneath the fossiliferous zone. This is important, as showing that here, at least, the sands have scarcely diminished in thickness, though, from the order of the beds as given by Dr. Fitton, it is plain that we cannot trace individual portions; for the sand and clay which should represent Nos. 4 and 5, seem here reversed in position.

The whole interpretation, however, of this Oxfordshire district must be postponed till after the description of the remainder of the Portland rocks in Buckinghamshire.

Buckinghamshire.

There is a singular uniformity in the deposits, which spread over a considerable district, here, commencing on the south at a line from Brill to Thame, and ending on the north at a line from Quainton to Stukeley, beyond which no deposits of this age have been traced. Numerous sections in this area are given by Dr. Fitton. Mr. Brodie has given part of that at Brill*; and the succession at Hartwell is figured by Sæmann† with much accuracy. A generalized account, therefore, of the beds will be of most value, indicating where each portion may best be seen (see figs. 8, 9, Pl. VIII.).

In some places the top of the Portland rock is uncovered or is followed by ferruginous sands of a far subsequent date; but in many the succeeding rocks are white limestones and dark clays with freshwater fossils, usually referred to the Purbeck. In these cases there is no such tumultuous river with large Portland blocks as has carved out the hollows at Swindon; but the beds follow in an undisturbed manner, as they do in the Isle of Portland and at Chicksgrove, or even more so. In the quarry at Hartwell there *is* a great erosion of the upper beds, and the space is filled with dark stony earth; but this is in the freshwater strata only, and there is no stone above to give a posterior limit to the age of the erosion. At Long Crendon also is a bed immediately above the Portland, which has at its base great pieces of a white calcareous stone imbedded in a greenish white clay; but these are not Portland stones, and there is no proof of erosion. At South Oving, at Quainton, and at Brill the succession is very regular, and no indication to the contrary is given in any of Dr. Fitton's sections. We may conclude, therefore, that there were never any more Portland rocks deposited in this district than those now seen, and that they are not merely diminished in appearance by the overlap of more modern strata.

No. 1. The uppermost Portland rocks in all the quarries seen are composed of compacted shell-brash—the size and quality of the particles probably depending on the shells broken up, as they vary very much. The absence of oolite in this district is remarkable (what does occur is in the Purbeck at Brill), a point in which these beds

* In Wright's Monograph of Brit. Foss. Echin. Pal. Soc. p. 354.

† De Loriol and Pellat, *loc. cit.* pl. i. fig. 7, and p. 189.

agree with those at Chicksgrove*. This upper Portland bed is often separable into two, the upper being more broken, but having abundant *Trigoniæ* at its base, which in most northern quarries are much perforated by small *Lithodomi*. The lower block makes a solid building-stone, which is often the object of the quarries. The total thickness of this portion is pretty uniform at about 4 feet, however much the minor more consolidated bands may vary. In the quarry at Bierton, near Aylesbury†, the character seems different; for the fossils are *Mytilus pallidus* and some unrecognizable bivalves, and the resulting rock is much softer. This latter character, however, is repeated at Coney Hill, near Over Winchenden, where is a very important section; examined, however, in the direction of the dip, along the road from Aylesbury to Thame, it retains the character at its escarpment, but is diminished to 3 feet. The ordinary *Trigonia* is *T. gibbosa*; but Sæmann mentions *T.? Pellati* as from here at Hartwell, and Dr. Fitton mentions the only Belemnite known in the Portland Stone as coming from this at Quainton.

No. 2 is a more or less creamy limestone, but not always retaining that character, and having a very fossiliferous band at the base. It is, indeed, divisible into three blocks, when the upper part is the most creamy and abounds in small well-preserved fossils, especially *Natica ceres*, the middle is a harder block, and the basal portion is hardened by the great abundance of *Trigoniæ* and other shells. At Coney Hill this part is thicker than usual, and the three blocks are 4 feet, 4 feet, and 1 foot respectively, the top one very rich in fossils. The lower parts of this are of considerable economic value in the northern portion of the area, where they are the object of the quarries for building-stone and lime; and a large part of the village of Whitchurch has this for its natural paving. Where the base is consolidated by shells, the thickness is from 8 to 9 feet on the whole; but towards the south the lower part loses its abundant shells, which become more uniformly distributed, and it becomes a brown non-creamy limestone, called the "greys," with an underlying whiter rock, making, with the upper creamy parts, a total thickness of 13 feet. These features are seen in the quarries at Brill and Crendon. From Dr. Fitton's account of a pit near Stukeley, it would appear, on the other hand, to diminish towards the north. The fauna of this portion is extensive.

Fossils of the Creamy Limestones of Buckinghamshire.

c. Ammonites boloniensis (*De Lor.*).	Natica elegans (*Sow.*).
c. —— triplex (*Sow.*).	c. —— ceres (*De Lor.*).
—— pseudogigas (*Blake*).	—— incisa (*Blake*).
Belemnites, sp. ‡	(—— Marcousana §).
Alaria Beaugrandi (*De Lor.*).	(—— Hebertana §).

* The Purbeck beds here also agree in having flinty masses in them.

† The spot is marked by a fault on the Survey Map, and Gault and Greensand introduced, of which there is no sign in the quarry.

‡ *Fide* Dr. Fitton.

§ *Fide* M. Sæmann. I have seen none like them, though looking particularly for them.

Cerithium portlandicum (*Sow.*).
—— Hudlestoni (*Blake*).
Orthostoma acuticarina (*Blake*).
Pleurotomaria rugata (*Ben.*).
Pleuromya tellina (*Ag.*).
—— Voltzii (*Ag.*).
Neæra portlandica (*Cott.*).
Corbula dammariensis (*Buv.*).
Lithodomus, sp.
Astarte rugosa (*Sow.*).
Cyprina implicata (*De Lor.*).
—— elongata (*Blake*).
Cypricardia costifera (*Blake*).
Lucina portlandica (*Sow.*).
—— minuscula ? (*Blake*).
Anisocardia pulchella ? (*De Lor.*).
Cardium dissimile (*Sow.*).
—— calcareum (*Blake*).
c. Trigonia gibbosa (*Sow.*).
—— incurva (*Ben.*).
—— Pellati (*De Lor.*).
—— tenuitexta (*Lyc.*)?.
Arca Beaugrandi (*De Lor.*).
Nucula depressa (*Blake*).
Mytilus autissiodorensis ? (*Cott.*).
c. Perna Bouchardi (*Opp.*).
c. Pecten lamellosus (*Sow.* .
—— suprajurensis (*D'Orb.*).
Lima rustica (*Sow.*).
c. Ostrea expansa (*Sow.*).
c. —— bononiæ (*De Lor.*).
Exogyra bruntrutana (*Thurm.*).
Plicatula echinoides (*Blake*).
Serpula quinquangularis (*Goldf.*).
Echinobrissus Brodiei*, (*Wr.*).

The most characteristic of these is the little *Natica ceres*, which marks an horizon in the true Portlandian of Boulogne. The other *Naticæ* mentioned by De Loriol as found here by M. Sæmann come from the Boulognian grits; I have not been able to see any thing like them in Buckinghamshire. Of the fossils usually occurring in higher beds *Cerithium portlandicum* is only common in one place. *Lucina portlandica* and *Astarte rugosa* are rare. The first of these three seems always to be commonest in the uppermost beds of a locality, whatever their age; perhaps its presence is a sign of approaching freshwater conditions. The *Cardium* is the true *dissimile*, and not *Pellati*, which occurs abundantly below. The larger oysters are abundant; and the *Plicatula* is not rare. De Loriol mentions *Serpula coacervata* as common on the shells from this district; but the common *Serpula* is not that species, which I have seen nowhere from Portland rocks; it is not even *S. gordialis*, but a carinated species, which becomes abundant below.

No. 3. Throughout the whole district there is, underlying these limestones, a bed of yellowish brown sand, which is blue when first extracted. It is not at all glauconitic, and contains but few fossils. Towards the north, at Quainton, there is at the base a Serpulite, the species being *S. quinquangularis*; it does not form a hard rock, and reaches a thickness of 2 feet. The nearest spot to this at which this portion of the series is seen again, viz. Coney Hill, shows this to be very local, as it has diminished to 6 inches, and is not solely composed of *Serpulæ*. The whole thickness, however, a little under 5 feet, remains the same; and I have nowhere seen more than 6 feet. The only interest attaching to this bed is its constancy, and the fact that it occurs within the limits which we must assign to the Portland Stone as distinguished from the Portland Sand.

No. 4. This is a mass of rubbly limestone of very peculiar character, seen admirably in the quarries towards the north. Dr. Fitton mentions it in his section at Quainton as the "middle rock and rubble, abounding in fossils." It may still be seen there; but

* *Fide* Mr. Brodie.

its character is best observed at Coney Hill. Here about 8 feet are exposed, showing several layers of alternately large and small rubble, the large being composed of the internal casts of shells, which in some cases retain fragments of the shell attached; and yet, when they are extracted immediately from the rock, there is no sign of the rest of the shell in the matrix. We are therefore forced to the conclusion that the deposit is a redistributed one, the shells having become fossilized in an earlier matrix, from which they have been rolled out. The peculiar character of the fossils, as will be seen, points to the same conclusion. At an admirable section at Lodge Hill, made for drawing up stone for the building of a mansion at the summit, 12 feet of these rubbly beds appear, the base being imbedded irregularly in the underlying sand. They may also be recognized by their fossils, occupying the Great Western railway-cutting east of Aylesbury. At Brill, this part of the series can only be traced in a rough cliff-face over the brickyards; but some rubbly beds of the same character have a thickness at one place of 6 feet 6 inches. The following is the fauna observed:—

Fossils of the Rubbly Beds of Buckinghamshire.

Ammonites boloniensis (*De Lor.*).
—— pseudogigas (*Blake*).
—— triplex (*Sow.*).
—— biplex (*Sow.*).
—— pectinatus (*Ph.*).
Pleurotomaria rugata (*Ben.*).
Natica turbiniformis (*Röm.*).
Thracia tenera (*Ag.*).
c. Pleuromya tellina (*Ag.*).
Sowerbya longior (*Blake*).
c. Myoconcha portlandica (*Blake*).
Cyprina implicata (*De Lor.*).
—— Brongniarti? (*Pict. et R.*)
Unicardium circulare (*D'Orb.*).
c. Cardium Pellati (*De Lor.*).
r. —— dissimile (*Sow.*).
Mytilus jurensis (*Röm.*).
—— boloniensis (*De Lor.*).
c. Trigonia Pellati (*De Lor.*).
—— incurva (*Ben.*).
—— Voltzii (*Ag.*).
—— muricata (*Goldf.*).
—— gibbosa (*Sow.*).
—— Manseli (*Lyc.*).
—— Micheloti (*De Lor.*).
Perna Bouchardi (*Opp.*).
Lima rustica (*Sow.*).
—— ornata (*Buv.*).
—— bifurcata (*Blake*).
Pecten lamellosus (*Sow.*).
Ostrea solitaria (*Sow.*).
Plicatula Boisdini (*De Lor.*).
—— echinoides (*Blake*).
Serpula quinquangularis (*Goldf.*).
Glyphea, sp.

In this fauna the scarcity of Gasteropods is at once noticed; this may be accounted for by their having been destroyed in the breaking up of the old beds. The *Ammonites pectinatus* is an important introduction for the purpose of correlation. Its presence and the change of the common *Cardium* and *Trigonia* into other species, mark an earlier date; and several fossils which are new or peculiar have the same tendency.

No. 5. The section at Lodge Hill, before mentioned, shows a succession of sand and shell-beds, doubtless of the same character as No. 4, and of very little consequence, though here reaching 12 feet 6 inches. They are separated, because, on the one hand, they are not glauconitic, and, on the other, they are less constant than the overlying rubble beds. They are seen also in the cutting near Aylesbury, but towards the south they appear to die out, thus being complementary to the sand below.

No. 6. The glauconitic beds. These appear to have been seen in several places by Dr. Fitton where I can now find no exposure. At the Lodge-Hill cutting such stone is just visible, but there is not more than 16 feet between the top and the Kimmeridge Clay. In the brickyard at Hartwell, about 6 feet of very glauconitic material almost immediately overlies the Kimmeridge Clay. Similar rock is continued northwards to the Warren, Stukeley; and to the south of the area in the section at Brill, 5 feet of glauconitic matter is found beneath the rubble bed No. 4. These contain hardened masses of stone full of broken fossils, and at the base a pebble-bed full of Lydian stones. I have recorded only *Ammonites boloniensis*, *A. pseudogigas*, and *A. biplex* from these beds; but they have not been properly searched.

No. 7. The last of this series are argillaceous sands which lead down into the Kimmeridge Clay, but are not distinctly glauconitic. Like the lowest bed at Swindon, they chiefly differ from the true Kimmeridge Clay in being barren of fossils; and the two can scarcely be separated at Hartwell, while at Brill only 6 feet are seen. On the other hand, Dr. Fitton has recorded a thickness of 30 feet of sands near Thame, and stated them to contain huge calcareous doggers like those met with at Shotover. I have not been able to confirm this; but I think they mnst be a development of this part of the series.

The whole thickness of the Portland rocks in this district can thus be estimated on the average to be no more than 60 or 70 feet, including the sands at the S.E. corner. Thus a great reduction has taken place from Oxfordshire, and still more from Wiltshire. A similar reduction is seen in the underlying Kimmeridge Clay, as *Exogyra virgula* is reported a short distance below the pits at Hartwell. This reduction, however, is mainly due to the thinness of the Portland Sands, while the expansion or contraction of the Stone depends upon how it is related to the more southern deposits, which we must now proceed to discuss.

In the first place it is obvious that we can trace the same sequence in Oxfordshire as has been described in Bucks. The brashy beds above, the more consolidated beds below, with their base full of *Trigoniæ*, with *Ostrea expansa* and *Pleuromya tellina*, underlain by non-glauconitic sand, are all repeated; and in the space below are glauconitic beds and non-glauconitic concretionary sands. While, then, the tendency in the two counties is obviously for the sands to somewhat change their character by the dying-out of the concretionary beds as we pass to the north, the upper part remains sufficiently constant to justify us in seeking still further relations with the beds in Wiltshire, Bourton being no further removed from Great Hazeley than the latter is from Stukeley.

There are but two interpretations of the Buckinghamshire and Oxfordshire beds which can be advanced with any show of reason. The first and perhaps most natural assumption without particular study is, that we have here thin representatives of all the Portland deposits elsewhere reaching a far greater thickness. The other is, that we may match these beds with some part of those at Swindon, and that we have in them only a portion of the series elsewhere found.

We have seen, indeed, that the Swindon rocks are part only of those at Tisbury; but then the former are exceptional in other respects, and higher rocks may have been denuded there, which should be found again further north. There is therefore no particular presumption in favour of the latter interpretation, nor is there any against it; for though the Portland Sands below are seen to thin out, if we compare Portland, Swindon, Shotover, and Brill, the thinness of them at Tisbury, and perhaps also at Bourton, shows that this is not a general phenomenon. The point must therefore be decided by observation of detail.

If now we compare the northern sections with that at Swindon, and especially that part which is seen on the road to Coate, as detailed on p. 209, there is a certain amount of agreement—more than can be found by a comparison with any other part of the series. Towards the lower part the basal sands often consist of a kind of shelly brash, which will compare with No. 1. The two *Trigonia*-beds with the white chalky rock with *Cardia* recall well the three parts of No. 2, especially the *Trigonia*-bed at the base, which is seen both in Oxfordshire and, in a slightly different form, at Bourton. The glauconitic limestones below these, which are really much more sandy than those above, may well represent, in a changed aspect, the underlying sands, with their preceding rubble beds; or it may be that the clay of Swindon represents these. If we take this correlation and test it by the fossils, we shall find so remarkable a confirmation that no doubt is left in my mind as to its correctnesss. The following are found in both sets of deposits:—

Fossils common to the Limestones of Buckinghamshire and the Trigonia-*beds of Swindon and Bourton, and peculiar to these or most common in them.*

Ammonites pectinatus (*Ph.*).	*Pleuromya tellina (*Ag.*).
*Natica elegans (*Sow.*).	Thracia tenera (*Ag.*).
Trigonia Voltzii (*Ag.*).	Mytilus unguiculatus (*Ph.*).
*Cyprina elongata (*Blake*).	—— boloniensis (*De Lor.*).
*Cypricardia costifera (*Blake*).	*Echinobrissus Brodiei (*Wr.*).
*Anisocardia pulchella (*De Lor.*).	

Of these such as are marked with an asterisk occur in the creamy limestones, which are thus not to be separated as a higher part than that at Swindon. Other fossils have the same tendency. Thus, the Ammonites are those of low horizons, as are *Trigonia Pellati*, *Lima rustica*, *Exogyra bruntrutana*, and an abundance of *Ostrea expansa*, and *Pleuromya tellina*.

I regard, therefore, the whole of the limestones of Buckinghamshire as an expansion of the *Trigonia*-beds of Swindon, except that the brashy beds at the top correspond to part of the "basal sands" of the latter place, but not to the whole.

If this be the true correlation of the Portland limestones, it follows that, as the freshwater Purbecks succeed them without interruption, they must have been deposited during the period in which, at Tisbury and Portland, the remainder of the flinty series, the Whit-bed and the Roach were being formed, and they are thus older than some portions of the Portland rocks.

Summary.

The facts arrived at by this investigation may be briefly recapitulated as follows:—

In all the sections near the coast, the Purbeck is separated from the Portland by a line of clay; but the uppermost bed of the former is not always the same, and the line of junction, though not eroded, is irregular. The Portland series shows first the Whit-bed and Roach characterized by particular fossils, and especially by *Ammonites giganteus*, and lying with local unconformity on the next beds. The characters of this part differ in the various localities; and it almost thins out at Upway. It may be known as the Building-stone series. Below is the Flinty series, divisible into several parts, highly fossiliferous at the base, and characterized by *Ammonites boloniensis* &c. This is thickest at St. Alban's, and becomes very chalky at Upway. The Portland Sands contain a variety of beds (clays, cement-stones, and oyster-beds), and have a peculiar fauna distinct from the limestones above; but these characters are not constant. The thickness must be assumed much greater than has usually been done, unless the limit of the Kimmeridge Clay is unduly raised, and it is estimated at 277 feet. The Boulognian episode to which, unjustifiably, the name of Lower Portland has been given, is represented by normal shales and cement-stones on the Kimmeridge coast, all the beds being here much expanded, but recognizable by their general succession and the introduction at definite horizons of the characteristic invariant fossils.

In the Vale of Wardour the Purbeck is also marked off from the Portland by a band of clay, the succession is very similar, and beds corresponding to the Whit-bed and Roach may be recognized. The Flinty series is far less flinty and more chalky, and it has at its base a well-marked zone of fossils. A development of it downwards takes place here in the shape of some sandy freestones largely worked, containing several layers of *Trigoniæ*, especially one at its base. Below the limestones, the true Portland Sand is very thin and brown, and is underlain by a curious rubbly kind of stone appearing to belong, by its fossils, to an earlier date.

At Swindon the relations of the Purbeck to the Portland are most remarkable, the latter being carved out in hollows which contain rolled blocks of it, evidencing a land surface and rapid changes; but as the uppermost part of the Portland here corresponds only to the top of the freestones of Tisbury, and the higher parts are wanting, this erosion may have taken place in Portland times. The main mass of the quarried stone is of the same age as that at Tisbury; and at the base we find some fossiliferous beds in various well-marked blocks, and containing a peculiar fauna; these *Trigonia*-beds have a conglomeratic base, and are underlain by a local bed of clay, more allied to the beds below. The Portland Sands are found below this in the form of extremely fossiliferous sandstones or shell masses, which are glauconitic. They contain a well-marked fauna almost restricted to them. The base of the series is a thick mass of sands with huge concretionary masses in the lower part.

The districts of Oxfordshire and Buckinghamshire are made on the same model. The "Purbeck" beds of the latter county lie uniformly on the Portlands as in the south; but the underlying limestone corresponds to the *Trigonia*-bed of Swindon. Hence the former are of earlier date than the Purbecks of the latter place, and still earlier than those of the Isle of Purbeck, and were formed in Portlandian times. There are here still older deposits than at Swindon, which may yet be reckoned as belonging to the Portland Stone, consisting of redeposited beds with strange fossils. The fossiliferous Portland Sand is much diminished in importance, but continues its glauconitic character to the extreme north; while the lowest sands with their rounded masses are continued to Shotover and Thame, and there almost disappear.

Thus the Portland Sand had two maxima, one to the north of Tisbury and one to the south; but with regard to the Portland Stone, the oldest beds are found in the north, and as we go south later and later deposits are successively introduced before the traces of freshwater conditions appear. These were the final result of the gradual elevation in all cases, and were not of the same age throughout, but followed immediately on the period of the beds below.

It may be of interest to indicate the exact age of the different beds of the Portland series which are used for building-stones. In each case they owe their qualities to local conditions, and are not of necessity of any value because they can be geologically called "Portland Stone."

Building-stones of the Portland Series.

Locality.	Part of the series.	Observations.
Isle of Portland	(1). Roach.	Shelly.
	(2). Whit-bed.	The celebrated stone.
	(3) Top of the Flinty series.	Good stone.
Isle of Purbeck	(7) Middle of the Flinty series.	Suboolitic freestone.
Vale of Wardour	(2) A bed corresponding to the Whit-bed.	A beautiful white stone, ringing under the hammer
	(6) Lowest part of the Flinty series.	A soft freestone, very sandy.
Swindon	(2) Same part of Flinty series as the last.	Very irregular hard stone.
	(3) *Trigonia*-beds below the last.	Poor.
Oxfordshire	(3) Same age as the last.	A fair stone.
Buckinghamshire	(2) Same age as the last.	Ditto.

Conclusions.

Accepting the above results we can now give some account of the Portlandian episode in England. Remembering that little trace of any such episode can be detected either at Speeton or beneath Sussex, we learn that the elevation which introduced the circumstances capable of yielding sandy and calcareous deposits took place sporadically. We also know from the borings in London and at Ware that 30 miles from their most easterly outcrop the Portland rocks are not to be traced; but on this much reliance cannot be placed, for they may have been removed by precretaceous denudation. So far as our knowledge at present extends, the earliest rise took place along the main axis between Boulogne and the Mendips, and gave the peculiar character to the lower part of the beds west of Tisbury, while the Portland area was scarcely affected by it, and the clay to the north was rendered more sandy. Further physical changes of a nature unknown to us brought about the denudation of some sandy rocks and developed the great sandbacks, which pass from Swindon to Shotover and die away to the north-east, and which diminish from St. Alban's Head towards Portland and Upway and are not to be recognized in the Boulogne area. On the north side of the elevation these sands are partly glauconitic, the amount of green matter becoming greatest as they thin away to the north; while on the south side I have failed to find any glauconite, and on the line itself at Tisbury the slight thickness of sand exposed is brown as from the presence of a peroxide of iron. These peculiarities point to a different history of the deposits. The dark glauconitic (? all) grains are certainly not due to Foraminifera directly, calcareous specimens unfilled with dark matrix being present with them, and they having no shape derivable from such a source. Many of the dark-coloured stones are not glauconitic but Lydian stones.

Slight succeeding oscillations introduced the clay of Swindon and Portland and the upper bed of sand in Oxon and Bucks; but the seas were henceforth clear of these, and Mollusca flourished in one place to have their broken remains deposited in another, either of recognizable size or ground to the finest powder to form the chalky rocks. In one of these oscillations in the northern district a colony of Mollusca which had flourished and died and had their remains compacted to a rock, was broken up and the débris deposited again as the rubbly rock of Buckinghamshire.

The shallower sea to the north was soon nearly filled, while the axis of elevation travelled northwards, so that the former became an inland lake, and the accumulations at Swindon brought the sea-bottom so near the margin of the land that irregular deposits took place in it, though still marine ones. Shortly, however, this spot became dry land, suffering minor oscillations, marked by the erosion of bed after bed, the accumulation of unsorted débris, and the deposition of freshwater limestones. Meanwhile the sea to the south was still open, chalky and flinty masses of considerable thickness continued to be formed, varied at last by rougher deposits formed in more troubled water, till finally the last of the marine animals was killed off, and a wide area became exposed to the atmosphere. The freshwater conditions of the rocks of the Isle of Purbeck introduced a new era, which it is not my object to discuss.

With this history of the formation of the Portland rocks the earlier local elevations affecting countries to the south of England have nothing in common. They were not even the prelude to the changes above recorded; for after the Boulognian episode had begun and ended, the sea-bottom once more assumed its former position, and fresh deposits of clay (which had never ceased to fall on the British area) commenced again, and only gradually through the Portland Sands gave place to calcareous rocks. We may therefore rightly object to the use of the term Portlandian for rocks which neither in organic contents nor in physical history have any thing to connect them, and restrict the name to those which have formed the subject of the present description. We are even led to ask what amount of justification there is for the title Portland Sands as applied to the lower beds. If the choice lay between including these in the Kimmeridge Clay and including some more of the clay beds below them in the Portland series, I should unhesitatingly take the first alternative; for while the true Kimmeridge Clay has very little in common with the Portland Stone, it has much with the Portland Sand, and the latter has as much with it as it has with the Portland Stone. Moreover, in dividing the Portland Sand from the Kimmeridge Clay we have to draw a somewhat arbitrary line; but the line above is generally a well-marked one. It is these facts which have led the French geologists to include with the Portland Sand the upper part of the Kimmeridge Clay in one group, called by them the "Middle Portlandian." Yet, if there were no more to be said than this, the logical result would be the abolition of the Portland Sands. We have seen, however, that it is a variable mass developing local features and expanding and contracting in thickness, thus acting after the manner of an episodal formation and not like the normal Kimmeridge Clay. We have seen, too, that at certain spots a well-marked special fauna may be found in it. These features indicate that at the period of its deposition in any locality (a period which may have varied in *absolute* time from spot to spot) the tranquillity of the Kimmeridge sea-bottom had been disturbed, and those changes commenced which finally closed the Oolitic period in this country. To the final deposits due to these changes we give the name of Portland Stone; and hence to the results of their precursors, and to these alone, can we rightly give the name of Portland Sand.

List of Fossils of the Portland Series of England.

NOTE.—Names or stars enclosed in brackets indicate that the occurrence has been previously recorded, but has not been verified.	Base at Tisbury. V.	Shotover and glauconitic sands. IV.	Swindon sands and clay. III.	Lower sands of the coast. II.	Upper sands of the coast. I.	Rubble-beds of Bucks and Oxon. 8.	Creamy limestone of Bucks and Oxon. 7.	*Trigonia*-beds of Swindon. 6.	Freestone at Tisbury and Swindon. 5.	Upper beds at Swindon and Tisbury. 4.	Chalky series at Chicksgrove. 3.	Flinty series of coast. 2.	Building-stone of Portland. 1.
Belemnites, sp.	...	...	...	...	...	...	*						
—— Souichii, *D'Orb.*	...	...	...	*									
Ammonites giganteus, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	...	*
—— pseudogigas, *Blake*	...	*	...	...	...	*	*	...	...	...	...	*	
—— boloniensis, *De Lor.*	...	*	...	...	*	*	*	*	*	...	...	*	
—— triplicatus, *Sow.*	...	...	...	...	[*]	*	*	...	[*]	...	...	*	
—— biplex, *Sow.*	...	*	*	*	*	*	...	...	*	...	...	[*]	
—— pectinatus, *Ph.*	...	...	*	...	...	*	...	*					
—— Bleicheri ?, *De Lor.*	...	...	...	...	...	...	...	*					
—— Boisdini, *De Lor.*	...	...	...	...	*?	...	...	*	...	...	...	*	
Alaria Beaugrandi, *De Lor.*	...	...	...	...	...	...	*						
—— (*cf.* Thurmanni, *Cont.*)	...	...	*										
Buccinum naticoides, *Sow.*	...	...	...	...	...	...	[*]	...	...	...	...	...	*
—— angulatum, *Sow.*	...	...	...	...	...	...	...	...	...	*	...	...	*
Natica elegans, *Sow.*	...	...	...	...	...	[*]	*	*	...	...	...	*	*
—— elegans, *De Lor.* non *Sow.*	...	...	...	...	...	...	...	*					
—— ceres, *De Lor.*	...	...	...	...	...	...	*						
—— incisa, *Blake*	...	...	...	*	...	...	*						
—— turbiniformis, *Röm.*	...	...	...	...	...	*							
[—— Marcousana, *D'Orb.*]	...	...	...	...	...	...	*						
[—— Hebertana, *D'Orb.*]	...	...	...	...	...	...	*						
Pseudomelania (*cf.* multispirata, *Et.*)	...	...	...	...	...	...	...	...	...	...	...	*	*
Cerithium portlandicum, *Sow.*	...	...	...	...	...	[*]	*	...	...	*	...	...	
—— concavum, *Sow.*	...	...	...	...	...	...	...	...	...	*			
—— Bouchardianum, *De Lor.*	...	...	...	...	...	...	...	...	...	*			
—— Boisdini, *De Lor.*	...	...	...	...	...	...	...	...	...	...	...	*	
—— trinodule, *Buv.*	...	...	...	...	...	...	...	...	...	...	...	*	
—— bifurcatum, *Blake*	...	...	*										
—— Hudlestoni, *Blake*	...	...	...	...	...	...	*						
Turritella minuta, *Koch & Dunk.*	...	...	...	...	...	...	...	...	...	*			
Turbo Foucardi, *Cott.*	...	...	*										
—— apertus, *Blake*	...	...	...	...	...	...	...	...	...	...	...	...	*
Delphinula globosa, *Buv.*	...	...	*										
[Littorina paucisulcata, *Ph.*]	...	[*?]											
Neritoma sinuosa, *Morris*	...	...	...	...	...	...	[*]	...	...	*	...	...	*?
Nerita minor, *De Lor.*	...	...	...	...	...	...	...	...	...	*			
Trochus permedius, *De Lor.*	...	...	...	...	...	...	...	...	...	*			
Pleurotomaria rugata, *Ben.*	...	...	*	...	...	*	*	*	...	...	...	*	
—— Rozeti, *De Lor.*	...	...	...	...	...	...	...	...	...	...	...	*	
Rissoa acuticarina, *Blake*	...	...	...	...	...	...	*						
Pleuromya tellina, *Ag.*	...	..	...	*	...	*	*	*	*	...	*	*	
—— Voltzii, *Ag.*	...	*	*	...	...	...	*						
——, sp.	*												
Plectomya rugosa, *Röm.*	...	...	*	...	*								
Pholadomya tumida, *Ag.*	...	[*]	*										
Thracia tenera, *Ag.*	...	...	...	*	*	*	...	*					
Neæra portlandica ?, *Cott.*	...	...	...	...	...	...	*	...	...	*			
Corbula saltans, *Blake*	...	...	*[1]	...	...	...	*	...	*	...	...	*	*
Sowerbya Dukei, *Damon*	...	...	...	...	...	...	...	...	...	...	...	...	*

List of Fossils (continued).

	Base at Tisbury. V.	Shotover and glauconitic sands. IV.	Swindon sands and clays. III.	Lower sands of the coast. II.	Upper sands of the coast. I.	Rubble-beds of Bucks and Oxon. 8.	Creamy limestone of Bucks and Oxon. 7.	*Trigonia*-beds of Swindon. 6.	Freestone of Tisbury and Swindon. 5.	Upper beds of Swindon and Tisbury. 4.	Chalky series at Chicksgrove. 3.	Flinty series of coast. 2.	Building-stone of Portland. 1.
Sowerbya longior, *Blake*	...	...	*	...	...	*							
Myoconcha portlandica, *Blake*	...	...	*	...	...	*							
—— Sæmanni, *Dollf.*	...	...	*										
Cypricardia costifera, *Blake*	...	...	...	...	...	...	*	*					
Anisocardia pulchella, *De Lor.*	...	...	...	...	...	...	*	*					
Isocardia autissiodorensis, *Cott*	...	...	...	*	*								
Astarte rugosa, *Sow.*	...	...	...	...	...	[*]	*	...	...	*	...	[*]	
—— Sæmanni, *De Lor.*	...	...	*										
—— polymorpha, *Cont.*	...	...	*										
—— supracorallina, *D'Orb.*	*?												
[—— ovata, *Sow.*]	...	...	...	...	...	[*]							
Cyprina elongata, *Blake*	...	...	*[1]	...	*	...	*	*	...	...	...	*	
—— swindonensis, *Blake*	...	...	*	...	...	...	...	*?					
—— implicata, *De Lor.*	...	...	...	*	*	*	*						
—— puchella, *De Lor.*	...	...	*	...	...	...	...	*	*				
—— Brongniarti, *Pict. et R.*	...	...	...	...	...	*							
Unicardium circulare, *D'Orb.*	...	...	...	...	...	*	...	...	...	...	...	[*]	
Corbicella portlandica, *Damon*	...	...	...	...	...	...	...	...	...	...	...	[*]?	
—— Moræana, *Buv.*	...	...	...	...	...	...	...	...	...	*			
Lucina portlandica, *Sow.*	...	...	...	...	...	...	*	...	...	*			
—— plebeia, *Cont.*	...	...	...	...	...	...	...	*	...	...	*	*	*
—— fragosa, *De Lor.*	...	...	*										
—— minuscula, *Blake*?	...	...	...	...	...	...	*						
Cardium dissimile, *Sow.*	...	...	...	...	[*]	*	*	*	...	*	*	*	
—— Pellati, *De Lor.*	...	*	...	...	...	*	...	*					
—— ? calcareum, *Blake*	...	...	...	...	*	...	*	...	...	...	*		
—— Morinicum, *De Lor.*	...	...	*										
Trigonia gibbosa, *Sow.*	...	...	...	...	...	?	*	*	*	*	*	*	*
—— tenuitexta, *Lyc.*?	...	...	...	...	...	...	*						
—— Manseli, *Lyc.*	...	...	...	...	...	*							
—— incurva, *Benett*	...	...	*?	*	*	*	*	*	...	...	...	*	
—— radiata, *Benett*	*												
—— Pellati, *De Lor.*	*	*	*	*	*	*	*						
—— Voltzii, *Ag.*	...	...	...	...	...	*	...	*					
—— muricata, *Goldf.*	...	...	...	*	*	*	...	*					
—— variegata, *Credner*	*												
—— Carrei, *De Lor.*	...	...	...	*?	...	*?	...	*					
—— concentrica, *Ag.*	*												
—— Micheloti, *De Lor.*	*?	...	...	...	...	*							
—— cymba, *Cont.*	...	...	...	...	[*]								
—— swindonensis, *Blake*	...	*	*										
—— alina, *Cont.*	...	...	...	...	[*]								
Leda	...	...	...	...	...	...	...	...	...	*			
Nucula obliquata, *Blake*	...	...	...	...	...	...	*						
Arca Beaugrandi, *De Lor.*	...	...	*	...	...	...	*	*	...	*			
—— (*cf.* velledæ, *De Lor.*)	...	...	*	*									
Lithodomus portlandicus, *Damon*	...	...	...	...	...	...	...	...	...	...	...	*	
——, small sp.	...	...	*	...	...	...	*						
Modiola pallida, *Sow.*	...	...	...	...	...	...	*	...	...	...	...	[*]	

List of Fossils (continued).

	Base at Tisbury. V.	Shotover and glauconitic sands. IV.	Swindon sands and clays. III.	Lower sands of the coast. II.	Upper sands of the coast. I.	Rubble-beds of Bucks and Oxon. 8.	Creamy limestone of Bucks and Oxon. 7.	*Trigonia*-beds of Swindon. 6.	Freestone at Tisbury and Swindon. 5.	Upper beds at Swindon and Tisbury. 4.	Chalky series at Chicksgrove. 3.	Flinty series of coast. 2.	Building-stone of Portland. 1.
[Modiola bipartita, *Sow.*]	...	...	...	...	...	...	[*]						
Mytilus jurensis, *Röm.*	*	...	...	...	...	*	[*]	*	*				
—— unguiculatus, *Ph.*	...	...	...	...	...	...	...	*	*				
—— autissiodorensis, *Cott.*	...	...	*	*	*	*	*?						
—— boloniensis, *De Lor.*	...	...	*	...	...	*	...	*	...	...	...	*	
—— longævus, *Cont.*	...	...	*										
Pinna suprajurensis, *D'Orb.*	...	[*]	*										
Perna "mytiloides"	...	...	...	...	...	...	*	...	*	*	...	*	*
—— Bouchardi, *Oph.*	*	...	*	...	...	*	*	*					
—— ? Bayani, *De Lor.*	...	...	*										
Avicula octavia, *D'Orb.*	...	...	...	*									
Plicatula Boisdini, *De Lor.*	...	...	...	...	...	*							
—— echinoides, *Blake*	...	...	...	...	...	*	*	...	...	...	...	*	
Lima rustica, *Sow.*	...	...	...	...	[*]	*	*	*	*	...	...	*	
—— boloniensis, *De Lor.*	...	...	*	*									
—— ornata, *Buv.*	...	...	...	...	...	*	...	*					
—— bifurcata, *Blake*	...	...	...	...	...	*							
Pecten lamellosus, *Sow.*	...	[*]	...	...	*	*	*	*	..	*	*	*	*
—— suprajurensis, *D'Orb.*	...	...	*	...	...	...	*	...	...	...	...	*	
—— Morini, *De Lor.*	...	...	*	*	*								
—— solidus, *Röm.*	...	[*]	*	...	*	...	...	...	...	...	...	*	
—— concentricus, *Koch & Dunk.*	*?												
Placunopsis Lycetti, *De Lor.*	...	...	*										
Ostrea expansa, *Sow.*	...	...	...	...	...	...	*	...	...	...	*	[*]	
—— bononiæ, *De Lor.*	...	...	*	...	...	...	*						
—— multiformis, *K. & D.*	...	...	*	...	...	...	...	...	...	...	...	*	
—— solitaria, *Sow.*	...	...	...	*	*	*	*	...	*	...	...	[*]	
[Gryphæa dilatata, *Sow.*]	...	[*]											
Exogyra bruntrutana, *Thurm.*	*	...	*	...	*	...	*						
[—— spiralis, *Goldf.*]	...	...	...	...	...	...	[*]						
Waldheimia boloniensis, *Rigaux*	...	...	...	...	...	...	...	...	...	...	...	...	*
Rhynchonella portlandica, *Blake*	...	...	...	*									
Discina Humphresiana, *Dav.*	...	...	...	*									
Lingula ovalis, *Sow.*	...	...	...	*									
Serpula gordialis, *Schl.*	...	...	...	...	...	...	*	...	...	...	...	*	
—— quinquangularis, *Goldf.*	...	[*]	...	...	...	*	*						
Glyphea, sp.	...	...	...	...	...	*							
Echinobrissus Brodiei, *Wr.*	...	...	...	...	...	...	*	*					
Acrosalenia Kœnigi, *Desm.*	...	*	*										
—— brillensis, *Wr.*	...	...	...	...	...	...	[*]						
Isastræa oblonga, *Flem.*	...	...	...	...	...	...	...	...	*	...	...	*	
Chimæra Townsendi, *Ag.*	...	...	...	...	...	[*]?	...	...	...	...	...	*	
Pycnodus Bucklandi, *Ag.*	...	...	...	...	...	...	...	...	...	...	...	*	
—— pagoda, *Blake*	...	...	...	...	...	...	...	...	...	...	...	*	
Chelone?	...	...	...	...	...	...	...	...	...	...	...	*	
Steneosaurus gracilis, *Ph.*	...	[*]											
Ceteosaurus longus, *Owen*	...	...	...	...	...	[*]							
Goniopholis	...	...	...	...	...	...	...	...	...	*			

Notes and Descriptions of Portland Fossils.

Pycnodus pagoda, spec. nov. Pl. X. fig. 10.

A small species characterized by the very peculiar arrangement of the teeth on the vomerine bone, which is the only part preserved. The general shape of this is long and narrow. It is bounded by a series of close-set oval teeth on each side, with their long axes pointing inwards and backwards. The central line is occupied by six large transversely oblong teeth, which are so far separated as to allow between each pair two obliquely subtriangular teeth of intermediate size, having their axes pointing inwards and backwards. All these teeth are quite smooth.

In the Flinty series at Upway; found by J. Badcock, Jun., during the visit of the Geologists' Association.

Ammonites giganteus, Sowerby.

Portland Ammonites are commonly quoted under this title; but De Loriol has pointed out that Sowerby's description and figure do not apply to the specimens so named, which have more than twice as many exterior as interior ribs, while in Sowerby's species the ribs only occasionally bifurcate. Such occur only in the building-stones of Portland; and I have accordingly used De Loriol's name *A. boloniensis* for the others.

Ammonites pseudogigas, spec. nov.

I confer this name on certain specimens which have on the inner half of the whorl large knobby ribs which bi- and trifurcate. It has the whorl as much inflated as in *A. gigas*; but the ribs are more numerous than the knobs in the latter species and are more truly ribs.

Ammonites triplicatus, Sowerby. Pl. X. fig. 7.

The figure given by Sowerby is of a very small specimen, in which the characters are not well seen. There is, however, a species in the Flinty series to which this name has become attached, but which has never been properly figured, and it is therefore given in Pl. X. fig. 7. It is nearly allied to *A. hector*, D'Orb.; but the ribs pretty regularly divide into three, and not more, at the larger diameter, though the smaller ribs are at first four times as many as the large ones.

Ammonites pectinatus, Phillips.

This I think to be the same as *A. Devillei*, De Loriol, because the young of the latter has as numerous ribs as the former, according to the description, and a specimen showing the peculiar proboscis-like form of the aperture had also fine ribs on the inner whorls. Nevertheless *A. pectinatus* acquires a size larger than any known specimens of *A. Devillei* without showing the changes. If they be distinct, then *both* species occur in the Swindon Sands.

Alaria Beaugrandi, De Loriol.

This is a well-marked species, with two strong keels on each whorl, of small size, and pretty common in the creamy limestones of Bucks. See Mém. Soc. Nat. et Phys. de Genève, tom. xxiii. pl. ix. fig. 19.

Natica ceres, De Loriol. Pl. IX. fig. 2.

This characteristic species is well marked by its acute spire, well-separated whorls, and deep, almost ornamental lines of growth. The British specimens are perfectly consonant with the author's figures and description.

Natica incisa, spec. nov. Pl. IX. figs. 1, 1*a*.

This is very nearly allied to *N. ceres*, with which it is found associated. Its distinguishing characteristic is a broad depression running longitudinally along the upper part of the whorl, so that the top and middle line are swollen. There are deep, subornamental lines of growth; and these are crossed by closer-set fine longitudinal lines. The spire is short and not very acute. The umbilicus is moderate in size. *N. ceres* shows slight traces of a longitudinal depression and lines; but in this they are so marked as to render the shell more like *Neritoma sinuosa*.

In the creamy limestones at Coney Hill and Quainton, rather common; also in the Portland Sand, Portland.

Cerithium Hudlestoni, spec. nov. Pl. IX. fig. 3.

This has an apical angle of 17°; and five whorls are visible; they are only moderately convex and slightly separated. The ornaments are on the upper half of each whorl (*i. e.* nearer the apex); transverse ribs, thirteen in number, in the last two whorls; these have a gentle convexity backwards, and die off at each end, leaving the lower half uncovered. This has three sharp longitudinal lines; and four more, parallel to them and finer, cross the ribs. The base is covered by the longitudinal lines only. Length 4½ lines. This is nearly allied to *C. septemplicatum*, and is probably the same as De Loriol's examples figured in the 'Bulletin de la Soc. Sc. Hist. Nat. de l'Yonne,' 2nd ser. tom. i. pl. iii. fig. 4; but the ribbing and folding of Römer's species is much more regular.

In the creamy limestones of Coney Hill and Hartwell.

Cerithium bifurcatum, spec. nov. Pl. IX. fig. 5.

Apical angle 24°, whorls rather inflated, sutures distinct, last whorl, not including the beak, half as large again as the penultimate. Ornaments about eighteen elevated transverse ribs with a slight convexity backwards, strongest towards the top. Halfway across the whorl they give place to two smaller ones, one being the continuation of the original. These are all knotted by longitudinal lines of alternating strength, about eight in number. The base has only knotted longitudinal lines. Total length about ½ inch. This is somewhat similar to M. De Loriol's *C. Lamberti*, but differs in details.

In the Swindon Sands, west of Swindon.

Turbo Foucardi, De Loriol. Pl. IX. figs. 6, 6*a*.

The English specimens which I refer to this species have flattish whorls and well-marked sutures. The upper sloping part of the whorls has three granular longitudinal lines, the upper one having the largest granules; these are followed below by two strong granular ridges on the same level, with a concavity transversely striated between, this concavity forming the suture of the earlier whorls. The base has concentric granulose lines of unequal strength. It is imperforate and has a twisted columella. De Loriol states that his species has sometimes two rows of granules at the edge, in which case there is little difference.

Rather common in the Swindon Sands, west of Swindon.

Turbo apertus, spec. nov. Pl. IX. fig. 7.

This is only known as a cast. The spire is low, apical angle about 95°; whorls two, probably subquadrate and bicarinated, the upper keel the stronger. The aperture was greatly expanded; and the umbilicus was open. It seems worth while to name this, as it is rather common in the Roach; but at present it can scarcely be said to be known. I have seen no figures of foreign species of which this could be the cast.

Rissoa acuticarina, spec. nov. Pl. IX. fig. 4.

Apical angle 27°; whorls turreted, with a sharp keel, which is ornamented by fine transverse widely spaced lines. The last keel is thus divided into low knobs; and there are longitudinal lines on the base of the whorl. Length 2 lines. This is nearly allied to the *R. unicarina* of Buvignier; but the keel is so much sharper as to completely alter the shape of the whorl.

Rather common in the creamy limestones of Bucks.

Thracia tenera, Agassiz.

This name is used to denote a much broader shell than our ordinary *T. depressa*. The two species are frequently united by authors; but there do exist two perfectly distinct ones, and the Portland forms agree very well with Agassiz's figures, as do those of Boulogne.

Corbula saltans, spec. nov. Pl. IX. fig. 9.

Minute, length $\frac{7}{4}$ the breadth, valves very nearly equal, beaks nearly median, anterior side elliptically rounded; posterior side obliquely truncated, the hinge-margin remaining nearly parallel to the pallial border for some distance, and there being a flat area separated by a line which is *concave* towards the pallial border. This gives the shell a humpbacked appearance.

It is nearly allied to *C. fallax* and *C. dammariensis*; but neither of these has the shoulder-like posterior side.

Common in the creamy limestones at Coney Hill and Quainton, and in several other places.

Sowerbya longior, spec. nov. Pl. IX. figs. 8, 8*a*.

Length $\frac{1}{4}$ the breadth, beaks nearly median, valves moderately inflated; posterior angle well marked, almost produced at the pallial border; anterior side most convex towards the pallial border. Muscular impression deep. This differs from *S. triangularis* in the great length of the posterior angle, the more rounded pallial border, and more median beaks.

In the rubbly limestones near Aylesbury, and in the Swindon Sands.

Myoconcha portlandica, spec. nov. Pl. IX. fig. 10.

Only known by the cast, which cannot be referred to that of any known species. Its general form is spathulate; that is, it is thick anteriorly and becomes broader and thinner posteriorly. It appears to vary in shape in the different examples, possibly from the state of preservation. In some it is more curved than in the figured example. There are slight ridges on the cast radiating from the umbo; and the pallial line is crumpled; the shell had strong folds of growth, where preserved. The muscular impressions are well seen; the posterior one is large and remote. Length $4\frac{3}{4}$ inches.

Abundant in the rubbly limestones at Coney Hill, and found associated with *M. Sæmanni* in the Swindon Sands.

Cypricardia costifera, spec. nov. Pl. IX. fig. 11.

Valves inflated; apices recurved, nearly median; posterior side having its oblique area bounded by a raised rib, and concentrically striated, as is the rest of the shell obscurely; breadth a little less than the length. This is very like an *Isocardia*. Its rib distinguishes it from all others.

Moderately common in the creamy limestones of Coney Hill.

Astarte rugosa, Sowerby.

I cannot find any difference between this and *Astarte cuneata* among the numerous specimens I have seen. De Loriol affirms that its hinge is exactly like that of the Cyrenas of the Weald; but a comparison of it with the hinges of recent Cyrenas and Astartes, leaves no doubt of its belonging to the latter, especially from a peculiarity not perhaps noticed before, but very obvious on the casts from Swindon. In these and in Astartes only, there are very narrow lateral teeth and sockets, such that the posterior tooth is in the right valve, and the anterior tooth is in the left valve, fitting into sockets in the opposite valve, and so making a deep impression on the cast.

Astarte polymorpha, Contejean. Pl. IX. fig. 12, 12*a*.

These specimens agree very well with the author's description; but being very characteristic of the Swindon Sands, and possibly different from those occurring in the Osmington Oolite, they are figured for greater certainty. These are depressed; umbones nearly median. There are two or three deep concentric furrows, and three, five, or more well-marked ribs between. The hinge shows the same arrangement of alternate lateral teeth as noted above.

Astarte Sæmanni, De Loriol. Pl. X. fig. 5.

This is perfectly characteristic, and an important fossil for correlation. In the Swindon Sands of Swindon.

Cyprina elongata, spec. nov. Pl. IX. figs. 14, 14*a*.

Breadth a little more than $\frac{2}{3}$ the length; thickness of the double valves $\frac{2}{5}$ the length. Beaks a little anterior, rather prominent, anterior border subtruncately rounded; posterior side with a very feebly marked-off slope, which makes the border subtruncate; pallial border gently convex. Surface with concentric lines of growth. The ligament is often preserved in those behind the umbones. This differs from *C. implicata* by being more elongated, and hence less trigonal. Its thickness is also less.

Abundant in the *Trigonia*-beds of Swindon, the creamy limestones of Coney Hill, and in the Flinty series and upper part of the Portland Sand in the Isle of Portland.

Cyprina implicata, De Loriol. Pl. IX. figs. 13, 13*a*.

Our specimens agree perfectly with the type, and occur chiefly on a lower horizon than the last, namely in the rubbly limestones of Aylesbury, and in lower beds in the Portland Sand on the coast.

Cyprina swindonensis, spec. nov. Pl. X. fig. 2.

Breadth not quite two thirds the length; valves not very inflated; beaks $\frac{2}{3}$ anterior, not prominent; anterior border rounded, posterior border obliquely truncate, the hinge-line sloping downwards, and a broad ill-defined area extending from the umbo to the posterior side; pallial margin greatly and uniformly convex. Shell with rough concentric lines of growth. This has a resemblance to *C. Loweana*, Lycett; but its pallial border is not so convex, and the posterior region is more markedly truncate.

Common in Swindon Sands, Swindon.

Unicardium circulare, D'Orbigny. Pl. X. fig. 1.

D'Orbigny's short description of a *Unicardium* from Portland rocks, in his 'Prodrome,' "espèce circulaire, renflée, plus courte sur la région anale, ridée concentriquement," answers very fairly for our species, which Mr. Damon appears to have found also at Portland. In point of fact its chief feature is its circular outline; but it is not very inflated. It is not uncommon in the rubbly limestones of Quainton, Coney Hill, &c.

Cardium? calcareum, spec. nov. Pl. IX. fig. 15.

This is a rather obscure species allied to *C. Dufrenoycum*, Buvignier.

Height $\frac{5}{6}$ the length. Posterior side truncate, with an angular margin. No ribs seen on the truncated portion; the rest of the surface has fine concentric lines. It is not certain that this is a *Cardium*; but it only differs from *C. Dufrenoycum* in *appearance* by being broader and wanting the radiating ribs on the truncated part.

It is rather widely distributed, and is best preserved in the chalk of Chicksgrove.

TRIGONIA SWINDONENSIS, spec. nov. Pl. X. fig. 4.

Breadth $\frac{3}{5}$ the length, united thickness $\frac{3}{7}$ the length. The umbones situated very near the anterior border, not very prominent; the anterior border is only slightly convex, and rounds off rapidly, with a marked change of curvature into the pallial border, which is gently and uniformly rounded; posterior border rounded, passing into the pallial border. The posterior hinge-line is only slightly concave, and slopes but slightly, making the whole figure a rounded trapezoid. Escutcheon moderately narrow, concave, with its upper border raised; only lines of growth on its surface. Area narrow, by degrees becoming very slightly different in direction from the lateral portion of the shell. It is subdivided by a groove bounded below by very small tubercles. The area is bounded by two other rows, the lower set the larger. Lateral portions have the tuberculated costæ separated from the area by a very shallow depression; ribs not more than twelve in number, at first pointing posteriorly, and then making a rapid bend to the anterior side; the tubercles are compressed and strongest at the bend, dying off as usual anteriorly; lines of growth well marked. The elongated form permits only of comparison with *T. Pellati*, *T. muricata*, and *T. incurva*. From the first it differs by the direction of the ribs and its tubercled border of the area, from the second by the fewness of its ribs and the details of the area, and from the last by its oblong shape and regularity of ribs, though the specimen figured by Dr. Lycett in 'The fossil Trigoniæ,' pl. ix. fig. 4, under the latter name may very likely belongs to this.

In the Swindon Sands, west of Swindon.

LEDA, sp. Pl. IX. fig. 16.

A small example, looking as if it belonged to this genus, is figured from the freestones of Swindon; it may nevertheless be the *Corbula Bayani* of De Loriol.

PLICATULA ECHINOIDES, spec. nov. Pl. X. fig. 6.

General axis oblique. Upper valve slightly convex, most so at the apex, where the valves were adherent; four or five irregular lost ribs, rising to spines which are not prolonged into tubes; these ribs bifurcate, or are only marked by the spines; there are fine intermediate elevations, but no striæ; the lines of growth are conspicuous. Under valve undulating; spines, which are tubular, not confined to the elevations; the whole surface covered with radiating rounded riblets. This is very nearly allied to *P. echinus*, Deslongchamps, from the Kimmeridge Clay; but the spines on the more convex valve are far less numerous, and they are not produced into tubes. It differs from *P. virgulina*, Et., in its shape and the length of the spines. *Plicatulæ* all look so much alike that few venture to name them; there can be little doubt, however, that this is distinct.

It is rather common in the lower beds of the Portland Stone, as in the creamy limestone of Quainton.

Lima bifurcata, spec. nov.

I have not sufficiently good materials to illustrate this species; but it seems to me a distinct one. The two valves have very little convexity; and the general shape is like that of *Lima rudis*, but more quadrate. It has, in the cast, great rounded ribs, which towards the end bifurcate into two smaller ones, and this is its distinguishing feature.

It is not uncommon in the rubbly limestones of Coney Hill and Aylesbury.

Pecten Morini, De Loriol. Pl. X. fig. 3.

This characteristic Portland-sand fossil is distinguished by its bifurcating punctated striæ, which are very close-set.

Rhynchonella portlandica, spec. nov. Pl. X. fig. 8–8*d*.

Shell longer than wide, outline irregular, beak prominent; foramen of moderate size, its lower half bounded on each side by the deltidium. Imperforate valve very convex at first, short, sloping down in two long tongues and having three nearly obsolete ribs on each side, in addition to the median elevation. Perforate valve convex in the middle line at first, but soon bending round at right angles into a long tongue, so as to be concave from side to side; this tongue is generally simple, as in *R. acuta*, but appears to be variable, some having it bifid, or even trifid, but differing in no other respect from the type. There are ribs on each side of this valve corresponding to those on the other. There are no longitudinal riblets on this species, though the lines of growth are clearly seen. One can scarcely feel quite certain whether this is a distinct species from *R. subvariabilis*. That species comes from the Kimmeridge Clay of Pottern, Wilts, which is the equivalent of the Swindon and Hartwell clays, and therefore very little removed in time, if at all, from the deposits whence these are derived. These, too, have a singular resemblance to *R. variabilis* of the lias. The distinguishing features, as compared with the Kimmeridgian form, are (1) the greater inflation of the shell, so that a side view shows a triangle whose base is as great as its altitude; (2) the prevalence of *one* central fold only; (3) the smoothness of the surface; (4) the larger foramen. It is also very near to *R. Hoheneggeri*, Suess, but is more quadrate; and the latter, though common, is not found with a single fold.

Common in the lower part of the Portland Sand at Black Ven, Portland, and less common in corresponding beds at St. Alban's Head.

Note.—Of the fossils described from the Kimmeridge Clay (Quart. Journ. Geol. Soc. vol. xxi. p. 196) the name *Inoceramus expansus* had been previously used, and must be changed for *I. rasenensis*; and *Leda lineata* had been previously described by Rigaux and Sauvage, in the 'Journal de Conchyliologie,' under the title of *L. venusta*.

EXPLANATION OF THE PLATES.

Plate VIII.

Comparative Sections of the Portland Rocks of England, with a generalized theoretical section extending from St. Alban's Head to Buckinghamshire.

Plate IX.

Fig. 1. *Natica incisa*, Blake. Creamy limestones of Coney Hill.
2. —— *ceres*, De Loriol. Creamy limestones of Coney Hill.
3. *Cerithium Hudlestoni*, Blake. Creamy limestones of Coney Hill.
4. *Rissoa acuticarina*, Blake. Creamy limestones of Coney Hill.
5. *Cerithium bifurcatum*, Blake. Swindon Sands, W. Swindon.
6. *Turbo Foucardi*, De Loriol. Swindon Sands, W. Swindon.
7. —— *apertus*, Blake. Roach, Portland.
8, 8 *a*. *Sowerbya longior*, Blake. 8, Rubbly limestones, Aylesbury; 8 *a*, Swindon Sands, W. Swindon.
9. *Corbula saltans*, Blake. Creamy limestones of Coney Hill.
10. *Myoconcha portlandica*, Blake. Rubbly limestones at Coney Hill.
11. *Cypricardia costifera*, Blake. Creamy limestones of Coney Hill.
12, 12 *a*. *Astarte polymorpha*, Contejean. Swindon Sands, W. Swindon.
13, 13 *a*. *Cyprina implicata*, De Loriol. Rubbly limestones, Aylesbury.
14, 14 *a*. —— *elongata*, Blake. *Trigonia*-beds, east of Swindon.
15. *Cardium*? *calcareum*, Blake. Portland chalk of Chicksgrove.
16. *Leda*? sp. Freestones, Swindon.

Plate X.

Fig. 1. *Unicardium circulare*, D'Orb. Rubbly limestones, Coney Hill.
2. *Cyprina swindonensis*, Blake. Swindon Sands.
3. *Pecten Morini*, De Loriol. Swindon Sands.
4. *Trigonia swindonensis*, Blake. Swindon Sands.
5. *Astarte sæmanni*, De Loriol. Swindon Sands.
6. *Plicatula echinoides*, Blake. Rubbly limestone, Coney Hill.
7. *Ammonites triplicatus*, Sow. Flinty series, Portland.
8–8 *d*. *Rhynchonella portlandica*, Blake. Lower Portland Sand.
9. *Discina Humphresiana*, Davidson. Dwarf form. Lower Portland Sand, Black Ven.
10. *Pycnodus pagoda*, Blake. Flinty series, Upway.

Discussion.

Mr. Hudleston agreed generally with the author's conclusions; but he differed from him in one point—namely, in considering the "roach" to constitute a good geological horizon, an uppermost division of the Portlandian, characterized by the abundance of *Cerithium* and *Cyrena*. He quite agreed with Mr. Blake in his reading of the Swindon section. He commented on the absence of the Lower Portlandian (zone of *Ammonites gigas*) in the south of England.

Prof. MORRIS bore witness to the accuracy of the observations of the author. He referred to the bed of phosphatic nodules which, in the Aylesbury area, overlies the Kimmeridge, and contains a number of peculiar fossils. This bed has been traced for some distance. He regarded *Cytherea rugosa* as a form of *Cyrena* and indicating the first incoming of estuarine conditions. At Hartwell the transition from marine to freshwater conditions is very well marked.

Prof. SEELEY thought that part of the beds in the central districts, now regarded as Neocomian, are really, as supposed by William Smith, of Portlandian age. He regarded the Portlandian as essentially a sandy series, graduating down into the Kimmeridge Clay below and the Neocomian above, and considered that the Portland Limestones were mere accidents due to differences of condition.

Prof. T. R. JONES had not succeeded in finding fossils in the black clays of Swindon which would enable us to decide whether they are of freshwater or of marine origin. He noticed the occurrence of worn septaria on the top of the side of the quarry; and stated that he had found fossil wood, like that of the Purbeck beds at Portland, in another bed near the top. He remarked that a chalky bed in the Portland beds at Upway contains Cretaceous Entomostraca.

Prof. RAMSAY informed the author that the block in the Museum of Practical Geology, referred to in the paper as being Portlandian in the lower part and Purbeck in the upper, contained Cyprids in the higher part of it. He agreed with the author as to the physical geography of the district during the Portlandian period.

Mr. WHITAKER stated that at the time when the Geological Survey of Buckinghamshire and Oxfordshire was made it was found very difficult to separate the Portland Limestone from the Portland Sand.

Prof. WALTER KEEPING referred to the existence of Portlandian forms in the Potton and similar beds in the Midland Counties. He thought that these were derived from Portlandian strata, which must have been originally spread over wider areas. He thought that the black pebbles in the Portlandian and Potton beds are derived from Carboniferous rocks forming part of the great Palæozoic ridge.

The AUTHOR did not agree with Mr. Hudleston as to the limits of the *Trigonia gibbosa*. He did not regard the "roach" as a continuous deposit, since in different sections it occurs at different horizons. The zone of *Ammonites gigas* is certainly not to be differentiated as a distinct series in the Kimmeridge section. Possibly a representative of the Portland may exist in Lincolnshire. He did not regard Entomostraca as being always good characteristic fossils.

'ORTLAND

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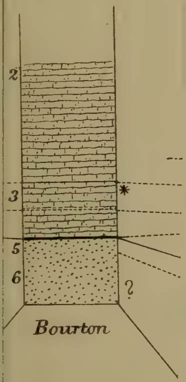

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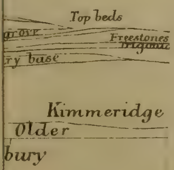
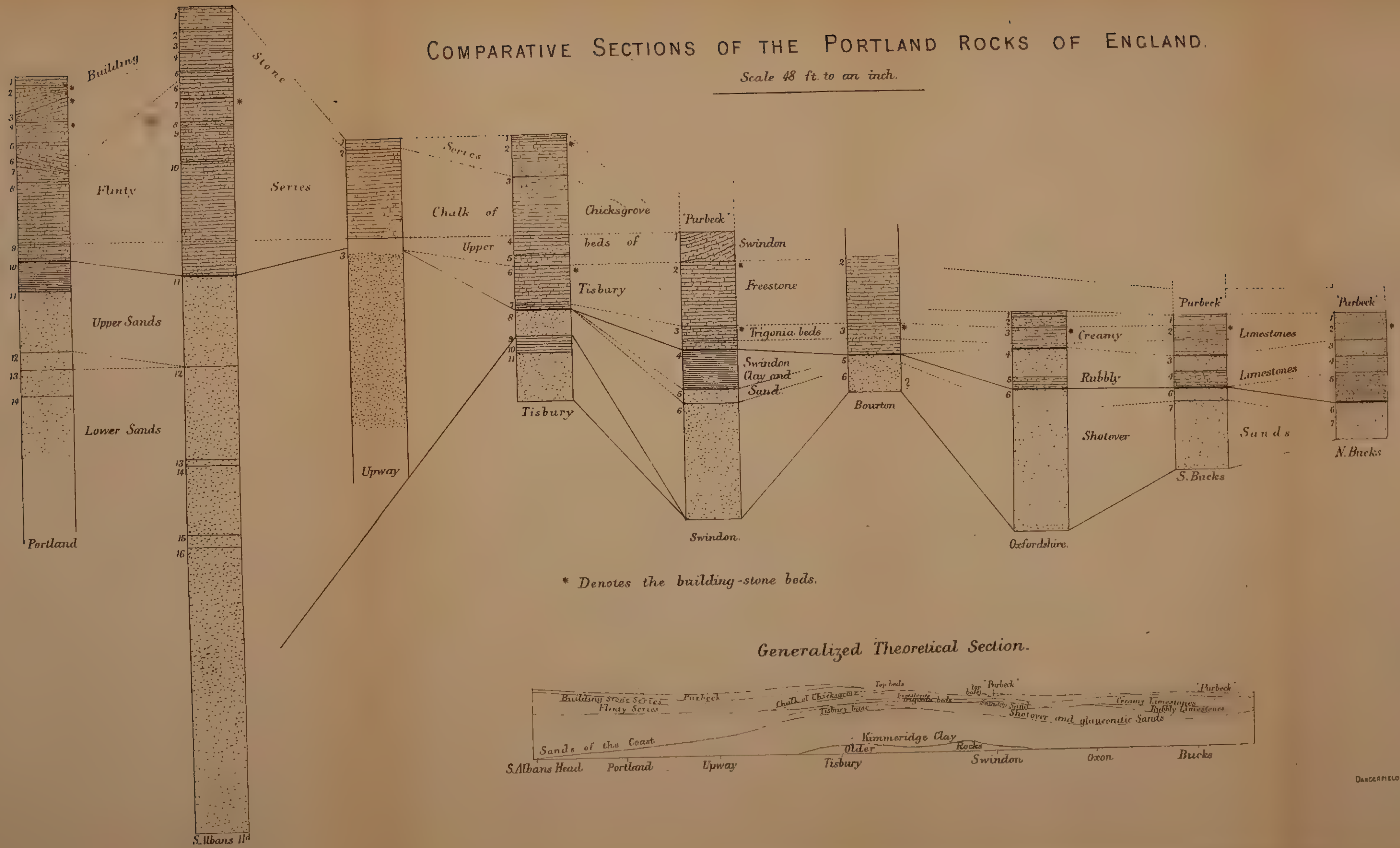


Comparative Sections of the Portland Rocks of England.

Scale 48 ft. to an inch.



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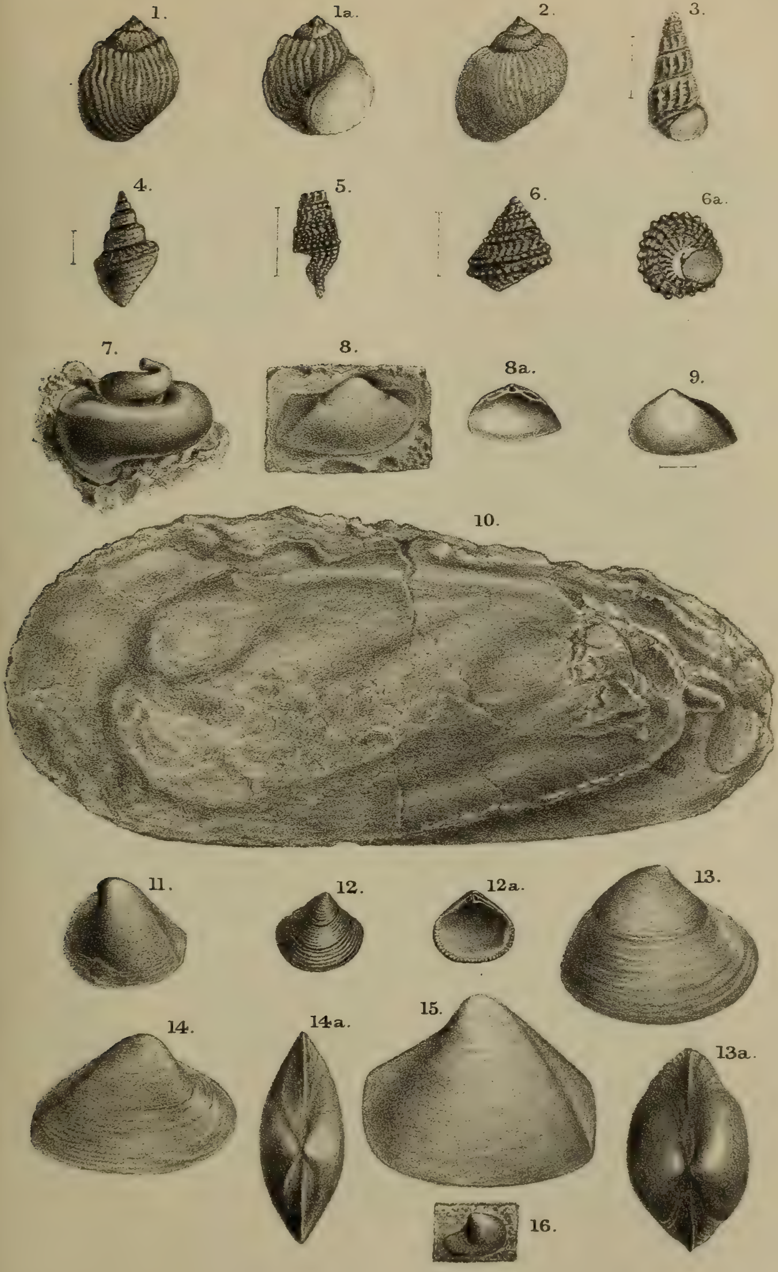

A. S. Foord lith

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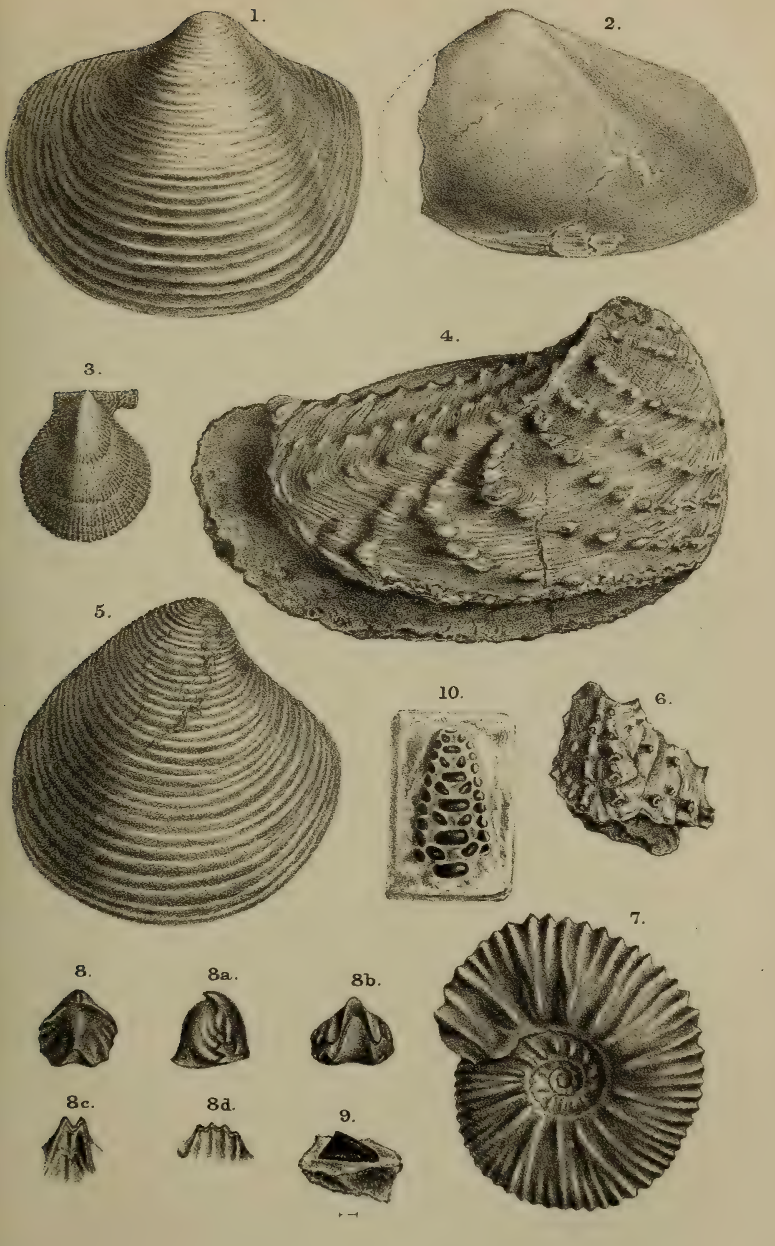
PORTLAND FOSSILS.



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PORTLAND FOSSILS.

15. *On the* Geology *of* Anglesey. By T. McKenny Hughes, M.A., F.G.S., Woodwardian Professor of Geology, Cambridge. (Read February 25, 1880.).

The rocks to which these notes chiefly refer were described by Prof. Henslow under the heads of Quartz Rock, Chlorite-schist and Grauwacke, in a paper read before the Cambridge Philosophical Society in 1821. He evidently considered them to be distinguishable members of one group, drawing attention to the passage from the quartzite into the schists, and to the generally coinciding dip of the clay slate and schists, even where, as at Porth Corwg, there is a small discordancy between the two, caused by a fault. He points out that green slates and brecciated conglomerates occur in the upper part of the black-slate group; but he records no fossils from which the geological horizon of the beds described can be determined, and his sections do not give much more than the geographical succession of the rocks over the areas referred to in this paper.

Prof. Ramsay (Mem. Geol. Surv. vol. iii. p. 175) describes the Cambrian and Silurian Rocks of Anglesey as in great part resembling those of Caernarvonshire. The Cambrian rocks, he further remarks, are, as a rule, highly metamorphic, like those in the promontory of Lleyn (Cambrian in his nomenclature includes only the Harlech group). The Silurian (*i. e.* the Lingula-flags and all above them), he goes on to say, are also sometimes metamorphosed into mica-schists and gneiss, while in other places they are rich in Caradoc or Bala and Llandeilo fossils. Unfortunately the genera and species of the Graptolites are not recorded except from one locality mentioned in the appendix, where it is said that *Graptolithus*, sp., and *Diplograpsus teretiusculus* occur near Glanygors. Probably the localities rich in Bala fossils are those referred to by Salter, in the Appendix, p. 258, where he says, "The multitudes of a dwarf variety of *Orthis calligramma* give a Caradoc aspect to the grits."

It is clear that the four great masses of gnarled schists, the Holyhead mass, the Amlwch mass, the Llangefni mass, and the Menai mass, were considered by Prof. Ramsay to be metamorphosed Cambrian, *i. e.* Harlech beds, with the exception of certain beds near Cemmaes and some in the central axis from near Llanfaelog to the north end of Llaneilian mountain, which are spoken of as altered Silurian.

By others since the great masses of gnarled shale have been considered to be Pre-Cambrian, and some of the conglomerates have been referred to a Pre-Cambrian part of the period still earlier than the gnarled shale.

Before we can with safety speculate upon the age of the gnarled series, it is desirable to endeavour to clear up the evidence with regard to the age of the fossiliferous grauwacke; and the following short communication deals chiefly with this question, the conclusion arrived at being that the beds hitherto referred to the Caradoc are Tremadoc, that they are succeeded by Arenig, and that there are higher slates among which we shall by and by probably identify the Lower Bala.

To work the section upwards, we notice that we always have the quartz-jasper conglomerates above the gneissic rocks. There is never any group like the gnarled series associated with the beds that immediately succeed the gneiss; but the quartz-jasper conglomerates pass by alternations of beds into grey sandstones, which weather brown or yellow, as may be seen in Porthlygan on the N.E. coast and along the N.W. flank of the central axis from Llanerchymedd to near Llanfaelog. This is clearly the "grit with multitudes of a dwarf variety of *Orthis calligramma*" that Salter spoke of. But the species is *O. carausii*, a plano-convex shell of smaller size and with fewer ribs than *O. calligramma*, and a characteristic Tremadoc fossil; I found also near Tyhen *Neseuretus ramseyensis*, another Tremadoc form. They exactly resemble specimens from the Tremadoc of Ramsey Island in the character of the rock and mode of preservation of the fossils.

The Tremadoc sandstones are succeeded by black slates, into which they often pass up by alternations, as may be seen along the coast N. of Porthlygan and beyond the fossiliferous sandstones N. and N.W. of Llanerchymedd. On the S.E. side of the central axis there is not so clear an exposure of the conglomerates and Tremadoc sandstones. Brown sandstones, however, occur near Llangwyllog church, and in a quarry a little to the south of it. Resting on these sandstones are black shales from which I procured a small fragment of a Trilobite and a number of Graptolites, most of which are common forms in the Arenig. These black shales twist round and are seen in the railway-cutting E. of Llangwyllog Station to be faulted against the green gnarled series. Mr. Lapworth has looked over the Graptolites for me, and refers them to the following species:—

Dicellograptus, n. sp. allied to D. sextans, *Hall*.
Diplograptus dentatus, *Brongn.*, sp.
—— foliaceus, *Murch.*
Climacograptus confertus, *Lapw.*
Climacograptus cælatus, *Lapw.*
Glossograptus ciliatus, *Emmons*.
And some new forms of *Diplograptus & Glossograptus*.

Hardly any of the specimens are sufficiently well preserved to show all the specific characters; therefore it is possible that when we have collected a larger number some of these determinations may be shaken, and it is probable that the list will be largely added to.

From the evidence before him, Mr. Lapworth is inclined to refer the bed to the middle part of the "black-shale group," expressing some doubt as to whether they should be called Highest Arenig or Lowest Llandeilo. The fragment of a Trilobite consists of three body-rings; and from the number of these in a given space, and the relative breadth of pleuræ to axis, it agrees very well with *Trinucleus Murchisoni*.

On the whole I am inclined to refer the Llangwyllog beds to the Arenig, and expect to find the Llandeilo forms by and by in the slates of Llanbabo and Llanelian.

We have therefore two horizons, Tremadoc and Arenig or Lower Llandeilo, pretty clearly determined by characteristic fossils. The beds with Graptolites at Llangwyllog rest on brown sandstones, and pass up into black slates or shales. On the west of Llanerchymedd an immense series of similar black shales succeeds the fossiliferous brown sandstones, passing up into slates with subordinate sandstones and, in the upper part, containing a few irregular beds of felspathic slates and breccias.

The black-shale group succeeds the brown sandstones everywhere with a general northerly or northwesterly dip from west of Llanerchymedd to the coast east of Amlwch, where they dip as if they passed under the green gnarled beds.

A difficulty occurs west of Llanerchymedd: What becomes of the black slates as we follow them S.W.? They must have thinned out or been faulted out or overlapped. I think we have faults and an overlap of the Treiorwerth beds.

In Henslow's collection in the Woodwardian Museum there are a few fossils labelled from Treiorwerth. I have not yet verified the locality by finding the fossils myself in place; but the rock looks like the grey calcareous sandy part of the felspathic brecciated conglomerate of Treiorwerth, and very different from the quartz-jasper conglomerate of the base of the Cambrian. The fossils collected by Henslow in the shale of Treiorwerth are mostly mere casts; but I think the following genera and species occur amongst them:—

Nebulipora, a form like N. lens and a smaller var.
Petraia elongata?
Atrypa marginalis, *Dalm.*
Meristella angustifrons, *M'Coy.*
——, sp.
Orthis calligramma (?), *Dalm.*
——, var. plicata, *Sow.*
——protensa, *Sow.*
Orthis, various sp., ? O. testudinaria, *Dalm.*, ? O. crispa, *M'Coy.*
Strophomena rhomboidalis, *Wilck.*
Euomphalus, sp.
And one specimen of a curious fossil, which, for the present, we can only suggest may be
Acantholepis Jamesii, *M'Coy.*

These fossils refer the beds with considerable probability to the May-Hill group, under which I include the Lower Llandovery; but they are not conclusive, and I hope on another occasion to offer further evidence on this head.

The great black-shale group appears to dip under the gnarled series; and it seems improbable that they are everywhere thrown down into this position by faults.

Another group of fossiliferous sandstones and shales overlies the gnarled series, as at Glanffynon and near Llanpadrig.

It seems therefore worth considering whether the gnarled shales may not be the equivalent of the Bala volcanic series deposited beyond the region of principal volcanic activity.

Discussion.

Prof. Ramsay said that in the area of Llanberis and Nantffrancon the Tremadoc slates had not yet been proved beneath the other Lower Silurian rocks. He had himself, with Mr. Etheridge, observed Arenig slates in Anglesey, between the Cambrian rocks and the Carboniferous Limestone north of Beaumaris. That had already been published. He could not agree that the grits and schists of the northern part of Anglesey could represent the Bala volcanic series of the mainland. These, in places, contained fossils.

He thought the northern region of Anglesey represented the Cambrian grits and slates of Caernarvonshire and Merionethshire; in the Anglesey district there was no trace of volcanic matter. The metamorphosis of the Anglesey rock was very great, as had long ago been noted by Sir H. De la Beche. He described the nature of the alteration these rocks had undergone. He held that the strike of the strata and other evidence proved faults in the districts where Prof. Hughes doubted their existence.

Dr. Hicks expressed his agreement with most of the remarks of Prof. Ramsay. He thought that the rocks were metamorphic; and that was proved by the specimens which Prof. Hughes had brought forward. He instanced cases of contortion alone not disturbing the general character of a rock. In this district all the rocks were highly altered; and he could not believe they were Bala beds, but that they were of Pre-Cambrian age. But he quite agreed with Prof. Hughes in his recognition of the Tremadoc rocks. They were, perhaps, a little nearer to the Lingula-flags. Faults of the kind required by the ordinary theory were common in them.

Prof. Bonney said that he thought much more convincing evidence was required before these schists, which he held to be truly metamorphic, could be regarded as altered Bala rocks; mere resemblance did not suffice; and such examination as he had made had led him to an entirely different conclusion from Prof. Hughes. It was very improbable that beds so much altered should overlie so great a thickness of comparatively unaltered beds.

Mr. Keeping mentioned some instances in the beds of Llandovery age, near Aberystwith, which indicated a structure similar to that described by the author; and expressed his doubts whether the schists were of Pebidian age. He thought there was much parallelism between the Lleyn peninsula and the island of Anglesey.

The President said that as regards the Lower Silurian rocks of Anglesey Prof. Hughes had added much to our knowledge. *Neseuretus ramseyensis* was a distinctively Tremadoc form; and *Orthis carausii* was quite distinct from *O. calligramma*, and also marked a Tremadoc horizon. He thought Mr. Lapworth's determination of Arenig Graptolites also might be thoroughly trusted. It was also possible that representatives of the Lower Llandovery beds might be present.

Prof. Hughes, in reply, said he was glad to have his views as to the unconformity near Treiorwerth confirmed by Prof. Ramsay, as it was in that area he suspected the overlap of the May-Hill beds. In the absence of fossils through a great thickness of sedimentary rock, the Gnarled Schists (unpromising rocks for search) agreed with the green slates of Chapel-le-dale. He had not seen any thing in the arrangement of the contorted laminæ in adjoining beds which could not be better explained by crushing than by foliation. He did not suggest that they were metamorphosed rocks, but sedimentary rocks outside the volcanic area altered by mechanical action; and he did not think that there was any thing in the minute structure or constituents of any part of the series inconsistent with this view.

16. *A* Review *and* Description *of the various* Species *of* British Upper-Silurian Fenestellidæ. By George William Shrubsole, Esq., F.G.S. (Read February 25, 1880.)

Plate XI.

I have been recently engaged in investigating some of the Palæozoic Polyzoa, more particularly the Upper-Silurian Fenestellidæ: the result I beg to lay before the Society.

The Silurian group of the Fenestellidæ has by no means proved hitherto so interesting a field for research as the Carboniferous series. I find that only three palæontologists have entered the field—Lonsdale, Portlock, and Prof. M'Coy. The former, in Murchison's 'Silurian System,' gives an account of four species of *Fenestella* and two allied forms, which are most likely *Fenestellæ*. Prof. M'Coy, in the Cambridge Catalogue, describes two more species, and Portlock one from the Silurian strata in Ireland, making nine species in all, viz.:—

Fenestella antiqua, *Lonsd.*, Murch. Sil. Syst. pl. 15. fig. 16.
—— Milleri, *Lonsd.*, ibid. pl. 15. fig. 17.
—— prisca, *Lonsd.*, ibid. pl. 15. figs. 15, 18.
—— reticulata, *Lonsd.*, ibid. pl. 15. fig. 19.
Retepora infundibulum, *Lonsd.*, ibid. pl. 15. fig. 24.
Gorgonia assimilis, *Lonsd.*, ibid. pl. 15. fig. 27.
Fenestella rigidula, *M'Coy*, Brit. Pal. Foss. pl. 1 *c*. fig. 19.
—— patula, *M'Coy*, ibid. pl. 1 *c*. fig. 20.
Gorgonia regularis, *Portl.*, Geol. Londonderry, p. 324, pl. 22. fig. 3.

Prof. M'Coy's portion of the work has the advantage of being full, clear, and definite. On the other hand, Lonsdale, from causes to which I shall allude, has not been so fortunate or successful in his descriptions. Indeed the work of Lonsdale in arranging the *Fenestellæ* of the Murchison collection can only be regarded as provisional. With the scanty material at his command it could not be otherwise. He says himself on this point, "It is very difficult to establish species from fragments"*.

To assist me in the work, I have carefully gone over all Lonsdale's type specimens of *Fenestella*, now in the Museum of the Geological Society, with the result that I can quite confirm what he says, that he had only "fragments" to work from, and those destitute of reliable specific character. For the most part they are mere fragments of the reverse side of the polyzoarium, weathered, showing, of course, no cellules, and altogether valueless for the accurate definition of any species. This state of things accounts for the ambiguity and generalities in Lonsdale's descriptions; while the absence of data, such as measurements of interstices, or dissepiments, or number of cellules, as adopted by Prof. M'Coy, renders it impossible, from his text, to distinguish between the various species. In not one of the Silurian species of *Fenestella* described by Lonsdale do I

* Murchison's Sil. System, p. 678.

find any reference to the number of pores between dissepiments or in any given space. This omission is fatal to the future recognition of the species. Hisinger * committed the same mistake in describing *Retepora reticulata*; and Prof. M'Coy remarks that in consequence "it is scarcely possible ever to determine Hisinger's species with certainty." Hence, from the same cause, Prof. M'Coy, in compiling the Cambridge Catalogue, found it necessary to describe anew two of Lonsdale's species of *Fenestella* from Dudley. There are probably in all not more than five species of Silurian *Fenestellæ*; and yet, with six species already described, Prof. M'Coy found a difficulty in assigning two of the ordinary types to any of the then described species. The two species which, in consequence, Prof. M'Coy described were *Fenestella rigidula* and *Fenestella patula*; the latter is only the young growth of one of the species. The type in the Woodwardian Museum is not sufficiently well preserved to say which of the several species. So it comes to this, that of the eight species of *Fenestellæ* described by Lonsdale and Prof. M'Coy, virtually only one species remains which is fully and accurately described so as to be recognized from the text, viz. *Fenestella rigidula*, M'Coy.

To one familiar with the appearance of the Carboniferous Fenestellidæ, with the wonderful order and regularity of their calcareous network, the first sight of Lonsdale's figures of the Silurian Fenestellidæ is puzzling, to say the least of it. Apparently they form a strange contrast to them in outward form—cells visible only in the upper part of the polyzoarium, carina enlarged, smoothed and rounded, interstices abnormally thickened, and dissepiments placed at all angles. One half of Lonsdale's drawings of *Fenestellæ* present these anomalous forms of growth. The question naturally arose, Have we here true *Fenestella*-growth? A careful examination of the various reputed species furnished the answer. The explanation of these peculiarities is that the conical base of several species of *Fenestella* is the subject of an abundant incrusting growth, which, in most cases, follows exactly the line of the insterstice, which it conceals, as well as the cell-aperture, at the same time not otherwise interfering with the general outline of the *Fenestella*. Unfortunately portions so covered over have become typical *Fenestella*, and as such appear in Lonsdale's drawings. Nor do I find any caution respecting this abnormal growth. Silence on this head leads me to suspect that the true nature of the growth was not detected, and, more, that it was positively regarded as part of the *Fenestella*. Indeed there is no doubt on this point—that Lonsdale was misled by the incrustation, which he distinctly notices and would regard as an indication of maturity on the part of the polyzoon; for when describing the specific characters of the genus, he says:—"In well-preserved specimens of the base of apparently old corals the pores or foramina on the side of one branch have united by growth to those on the side of the adjoining branch, and constitute solid bars, either stretching transversely and simply across the intervals, or uniting obliquely, three and

* Brit. Pal. Foss. p. 48.

sometimes more together"*. This admirably describes the appearance of the principal incrusting growth found on the base of *Fenestella*, and is also well shown in several of the drawings; but it has nothing whatever to do with true *Fenestella*-growth. There is no doubt about the polyzoary of the *Fenestella* undergoing a change with age; but it is not of the erratic character mentioned by Lonsdale, nor by the formation and junction of new cross bars at various angles. All that occurs as the polyzoon attains maturity is that the whole of the existing structure receives an additional thickening of calcareous matter; and, as will be readily seen, the oldest portion, namely the base, would receive in time the greatest amount of deposit, and consequent thickening of its part over the other portions of the polyzoary. Continuing my investigations respecting these incrusting organisms, I have found, in all, four species which thus disfigure and obscure the base of *Fenestella*. Two of these are found on Lonsdale's species; and two I have since discovered. The most common incrustation is apparently a coral, a portion of the case of which fills the hollow spaces between the lines of the interstices, which are crossed in an irregular manner by tabulæ, which seem to take the place of the dissepiments of the *Fenestella*. This particular organism is depicted in four of Lonsdale's drawings of *Fenestella prisca*†. Another parasite, in the sense I have mentioned, is an *Aulopora*, whose lines of growth run smoothly along the interstice, greatly increasing its dimensions, while here and there are given off the characteristic tubular bodies. This is also seen in the drawing of *Fenestella Milleri*‡. Another of the organisms might be an incrusting polyzoon, judging from the peculiar branched or lobed bodies which are alternately given off from the stem, which follows the line of the keel of the interstice of the *Fenestella*. Another species is very similar in structure to some of the Alveolites of the Carboniferous Limestone. This I have found incrusting one of the preceding growths.

It is obvious that in the weathering which the remains have undergone the outer organism would suffer the most; notwithstanding this, all the incrusting forms mentioned can be satisfactorily made out. I may mention, in connexion with these incrustations, that the growth invariably commenced at the base, and rarely extended beyond one inch from that point. I have in no case found it on any other portion of the polyzoarium. From this I infer that in time there was a loss of vitality at the base of the polyzoon, which allowed the growth of the several incrustations.

When *Fenestellæ* became thus obscured by parasites and worn away by weathering, we cease to wonder at the confusion and uncertainty attending Lonsdale's species. And more, with every wish to do justice to an early worker and careful observer among the Polyzoa, it is not possible, with the material left by him at our disposal, to make out the species intended. The only course which I see open is to follow Prof. M'Coy's example, and begin *de novo* by describing

* Murch. Sil. Syst. pp. 677, 678.

† Murch. Sil. Syst. pl. 15. fig. 15.

‡ Murch. Sil. Syst. pl. 15. fig. 17.

the remaining species left undescribed by Prof. M'Coy. Before doing so I ought perhaps to say something more in justification of the extreme course I have adopted in setting aside the several species of Lonsdale's *Fenestellæ*, and will therefore notice them more in detail.

FENESTELLA ANTIQUA, Lonsd., Murch. Sil. Syst. p. 678, pl. 15. fig. 16.

This is the first of Lonsdale's species, and synonymous with the *Gorgonia antiqua*, Goldf., which has long been accepted as a *Fenestella*. This reference to Goldfuss's well-known drawing clears up any mystery there may be about Lonsdale's species. Goldfuss's type is from the Devonian of the Eifel. A very superficial acquaintance with the subject is sufficient to enable any one to know that there is little affinity between the Devonian and Silurian forms of *Fenestella*. On the other hand, the Devonian may well be compared with the Carboniferous. I have no doubt that the *Gorgonia antiqua*, Goldf., is the equivalent of the *Fenestella plebeia*, M'Coy. On the other hand, I know of no species in the Dudley Limestone that could be compared with *Gorgonia antiqua*, Goldf., or its better-known representative the *Fenestella plebeia*, M'Coy. In this view I am borne out by Prof. M'Coy, who states that *Gorgonia antiqua*, Goldf., "does not probably occur in Silurian strata"*. The principal point of resemblance that I see between the drawings of Lonsdale's and Goldfuss's species is, that they are both very much denuded and unfit for typical work. If I might hazard a conjecture as to the species, from the fragment figured by Lonsdale, I should say that it is an eroded fragment of the somewhat overdrawn *Fenestella rigidula*, M'Coy. The unsoundness of this reference to *Gorgonia antiqua*, Goldf., is seen in the fact that some years later Murchison, in 'Siluria,' states that *Fenestella antiqua*, Lonsd., is now assigned to *Fenestella subantiqua*, D'Orb.†, and further mentions that it is both an Upper and Lower Silurian species.

FENESTELLA PRISCA, Lonsd., Murch. Sil. Syst. p. 678, pl. 15. figs. 15 & 18.

Several drawings of the conical base of this species are given as typical examples of *Fenestella*-growth to illustrate the genus. Most of them are so disfigured by the coral growth previously mentioned, as wholly to conceal the *Fenestella*‡. Again, the type is from the Devonian of the Eifel, the *Retepora prisca*, Goldf., and with no more success than in the case of *Fenestella antiqua*; for, apart from other considerations, the drawing of the Silurian species when enlarged scarcely equals the natural size of *Retepora prisca*, Goldf. This difference in size is fatal to its identity with Goldfuss's species, apart from the indistinctness of the drawings. Indeed the error seems to be admitted, since in Murchison's 'Siluria' it is mentioned that the *Fenestella* formerly referred by Mr. Lonsdale to *Fenestella prisca*, Goldf., is now *Fenestella Lonsdalei*, D'Orb.§ The drawing of

* Brit. Pal. Foss. p. 50.
† Murch. Siluria, p. 180.
‡ Murch. Sil. Syst. pl. 15. figs. 15*, 15 *a* *, 15 *b* *, 15 *c* *.
§ Murch. Siluria, p. 216.

it is a reproduction of the cup-shaped *Fenestella* base, with the appearance of reversed fenestrules from incrusting remains, as originally given by Lonsdale in the 'Silurian System.' The value of this reference to D'Orbigny is considerably lessened when it is known that he takes Lonsdale's *Fenestella prisca* for the type of his new species, offering the very doubtful advantage of a change in the nomenclature only. The same mode of treatment is adopted in the case of *Fenestella antiqua*, Lonsd., which became the type of D'Orbigny's *Fenestella subantiqua*. I have mentioned that most of Lonsdale's drawings of *Fenestella prisca* are disfigured by the enveloping coral to which I have alluded. On the other hand, *Fenestella Milleri*, Lonsd., is covered with a species of *Aulopora*. In practice, I find that in our museums it is usual to assign the *Fenestella* base, covered as in *Fenestella prisca*, to *Fenestella Milleri*. It is not a matter of much moment, since the identity of this particular species is past recovery; the probabilities of the case are in favour of their being the same species. This growth on *Fenestella prisca* is readily detected by the peculiar shape of the so-called fenestrules, which are often twice as broad as long. What I take to be the tabulæ of the coral occur more frequently than the dissepiments of the *Fenestella*; hence the alteration in the shape of the fenestrules. This in itself is quite a reversal of the usual order of growth, and a feature as yet unknown in the Fenestellidæ. Prof. Nicholson, indeed, mentions an instance (*Fenestella filiformis* *, from the Devonian of America) in which the order of the fenestrules is thus reversed. The identification of this species as a *Fenestella* I consider to be reasonably open to doubt, since the author states that the poriferous face is unknown, thus leaving the true character undetermined. Can it be that the poriferous face is covered up with some foreign growth, as in the Silurian forms? It seems strange that, as in this case, the attempt should be made to describe a new species of Polyzoa without having seen the cells or celluliferous face. I may remark here that this is not the first time in which the incrustation on *Fenestella* has proved a source of error to palæontologists. Something akin to this led Prof. M'Coy to found the genus *Hemitrypa*, which in a former paper I showed to be *Fenestella membranacea* (Phil.), incrusted by a minute coral or polyzoon†. This is from the Carboniferous Limestone. Phillips mentions a similar form in the Devonian Limestone.

Five years after arranging the Silurian Polyzoa we find Lonsdale suggesting the parasitic nature of the genus *Hemitrypa*, in reference to some fossils from Van Diemen's Land‡. He makes no allusion whatever to the occurrence of the same growth among the Silurian group of Polyzoa.

Fenestella reticulata, Lonsd., Murch. Sil. Syst. p. 678, pl. 15. fig. 19.

The specimen in the Museum of the Geological Society is a frag-

* Geol. Mag. 1874, p. 199. † Quart. Journ. Geol. Soc. vol. xxxv. p. 282.
‡ Darwin's 'Volcanic Islands' (1844), p. 168.

ment of the reverse face, showing, of course, no cells, and therefore valueless for specific purposes. It is not possible with such material to determine the species. The species is lost; for the most that can be said of it is that, judging from the irregular character of the fenestrules, as given in the sketch, it is the young stage of some *Fenestella*.

Fenestella Milleri, Lonsd., Murch. Sil. Syst. p. 678, pl. 15. fig. 17.

This was intended by Lonsdale to be a new species. The type specimen in the Museum is the conical base of apparently a *Fenestella*, with the coral growth incrusting and wholly concealing it, so that not a cell-opening is visible. Lonsdale says that "the pores are most apparent in the upper part," evidently because of the growth around the base. The drawing shows this to be a species of *Aulopora*. With the specimen and drawing both silent, and specific details absent, the species lapses as a matter of course. Prof. M'Coy encountered all this, and felt the impossibility of recognizing Lonsdale's species, and, still unwilling that the name of one who did good work at the Crinoids should be set aside, resolved to revive the name for a newly found Bala species, a very much larger and different form in every way, and one that does not occur in the Dudley beds. Some fifteen years after the publication of the 'Silurian System,' Murchison, in 'Siluria,' gives for the first time a sketch of the pore-face of *Fenestella Milleri*, Lonsd. Meantime, as we have seen, Prof. M'Coy had appropriated the name to another species from another horizon. The question now arises, which of these species should retain the old name—the one from Bala or that from Dudley, Lower or Upper Silurian?

I think that Prof. M'Coy's species should still be known as *Fenestella Milleri* from the circumstance that it was the first to be adequately described, while Lonsdale gave a name only, and no proper description of the species. Another reason for this decision is that there is good reason for believing that Murchison's *Fenestella Milleri* of 1854 is only *Fenestella rigidula*, M'Coy, without the doubtful appendages on the keel.

Retepora infundibulum, Lonsd., Murch. Sil. Syst. p. 679, pl. 15. fig. 24.

This is a true *Fenestella*. In mistake Lonsdale assigned it to *Retepora*. He says of it, "The arrangement of the pores is similar to that in *Fenestella*, but on the inner, and not the external surface." As a rule the greater number of the Silurian Fenestellidæ have the pore-face on the outside of the polyzoarium, but not all. This arrangement of outside pores prevails in those species having the conical or cylindrical base. Others which are widely cup-shaped, with a more open arrangement of the fenestrules, have the pores on the inner side, in this respect corresponding to the Carboniferous species.

Lonsdale was clearly in error in giving generic value to the circumstance that in this particular *Fenestella* the cellules were on the inner instead of the outer surface of the polyzoary. The generic differences between these fenestrate forms, thanks to the labours of Prof. M'Coy, are now much better understood; the fact that this form has the pore-face on the inner side of the polyzoarium is not sufficient to ally it with *Retepora*. I cannot say more about this species than that it is a true *Fenestella*. I have seen three specimens; and in each case the pores were not visible. This recovered species will not increase the number on the list, since there is good reason to believe, from the thickened nature alike of interstice and dissepiment, that it is only the aged condition of one of the existing species.

Gorgonia assimilis, Lonsd., Murch Sil. Syst. p. 680, pl. 15, fig. 27.

This is a polyzoon of large dimensions. Lonsdale remarks of it that "it is impossible to determine if the fossil be a true *Gorgonia*; but, from its great resemblance to the axis of some existing species, I have ventured to place it in that genus" *. Prof. M'Coy regarded it as a true *Gorgonia* †, and mentions the occurrence among the Carboniferous fossils of some specimens referable to this "obscure species" as he calls it. Lonsdale's drawing of this species shows a fragment of the base. The branches are said to anastomose—a feature pertaining to *Retepora*, but not to *Fenestella*, whose branches are united by dissepiments. If the drawings and description are to be received as exact, then there can be no doubt of its being a *Retepora*. At the same time, I think that Lonsdale intended to describe a large form of *Fenestella* which is common in the Dudley Limestone, while from some defect he gave it characters which would assign it to another genus. One thing is clear, whether Lonsdale's species be a *Retepora* or *Fenestella*, it has not as yet been described in either genus. To avoid the difficulty which might arise if a true *Retepora assimilis* should be found, it will be well to describe it under the name of *Fenestella reteporata*, for reasons which I shall allude to later on. In 'Siluria' it is stated that *Gorgonia assimilis* is *Fenestella assimilis* ‡. No description is added; and the drawing is that of the fenestrules only, thus practically leaving the form undescribed.

Fenestella patula, M'Coy, Brit. Pal. Foss. pl. i. C. fig. 20.

I have examined the type specimen in the Woodwardian Museum, and find that it is only the young frond of one of the described forms, so far as I can ascertain. The cells are not so visible as they are made to appear in the drawing. There is no good reason for regarding it as a separate species. Its retention, therefore, on the list of Silurian species is unnecessary. Its case is analogous to that of *Fenestella frutex*, M'Coy, which is an early stage of *Fenestella plebeia*, M'Coy.

Fenestella regularis, Portl. Geol. Londonderry, p. 324, pl. 22, fig. 3.

This species Portlock described and figured from the Silurian

* Murch. Sil. Syst. p. 680. † McCoy's Carb. Foss. Ireland, p. 196.
‡ Murchison's 'Siluria,' p. 215, 216.

schists of Desertcreat, Ireland. Unfortunately, the reverse only was exposed; consequently the details by which alone it could be recognized are unknown. The polyzoary, from its wide, nearly flat expansion, would seem to favour the supposition that it belongs to the Carboniferous rather than the Silurian type of *Fenestella*.

Coming now to speak of the species to be described, I may truly characterize them as having strong individual features, which clearly define them, not only from one another, but also from their congeners in other formations. It will be seen that I have considerably reduced the number of species. In the state of uncertainty in the past as to their real character, it is impossible to say to what extent they may have been repeated. I by no means wish it to be understood that I consider the present list as to the number of species either full or complete. There is work yet to be done; the main details, and character of *Fenestella* (*Retepora*) *infundibulum* (Lonsd.) remain to be worked out. In addition, I have traces or fragments of two other species, the details of which are not sufficiently complete to warrant publication. One species is intermediate in size between *Fenestella lineata* and *Fenestella reteporata*; the other is much smaller than any *Fenestella* I have yet met with from either Carboniferous or Silurian formations. It has one hundred and twenty-five interstices measured transversely to the inch. I would suggest that it should be provisionally known as *Fenestella dudleyensis*. As revised, the Silurian species of the British Fenestellidæ will be as follows:—

Fenestella rigidula, M'Coy, Brit. Pal. Foss. p. 50, pl. i. C. fig. 19.

This species and *Fenestella patula* were first described in the Cambridge Catalogue. I have not succeeded in tracing it either in the Woodwardian Museum or elsewhere. The marked peculiarity about it is the double row of small cells on the keel. This I have not been able to verify. It is due to Prof. McCoy to state that Hall describes an American form, *Fenestella elegans*, as having the keel "margined on each side by a row of small oval cells" *. I have mentioned before that I regarded the character of this species as somewhat exaggerated. My reason for so saying is that Prof. M'Coy was clearly in error in claiming the same exceptional cell-character for some of the Carboniferous species, which have proved to be not true cells, but prominences, the remains of a former ornamentation. The difficulty is not lessened in consequence of its being stated that the cells are only half the size of the ordinary ones. Now *Fenestella intermedia*, it is true, does carry in part a cell on the keel, but then it is of the same size as the other cells. I strongly suspect that this feature of the inferior cell is very much overstated. The explanation is probably the following:—Some years ago, what is now known as a prominence on the keel of *Fenestella*, the remains of a spiniferous ornamentation, was regarded in some way as a reproductive organ. Lonsdale termed them "abraded vesicles" †, while Prof. King

* Hall, Pal. New York, vol. ii. p. 164

† Geology of Russia, vol. i. App. A. p. 630.

would regard them as "gemmuliferous vesicles" *. At any rate the drawings and description of this species are so circumstantial that we cannot do otherwise than retain it, notwithstanding the doubts I have expressed as to its identity.

Fenestella reteporata, sp. nov. Plate XI. figs. 1–1 *c*.

Sp. char. Polyzoary, base conical, opening outwards, forming expansions of considerable size. Interstices—obverse, strong, sinuous, keeled, rounded, often angular from erosion; reverse, striated longitudinally: four interstices in the space of two lines transversely. Keel strong, rounded. Dissepiments often less in size than interstices, recessed, not so wide as fenestrules, giving in consequence a waved line to the interstice; two dissepiments in the space of two lines longitudinally. Pores small, circular, less than their diameter apart when not worn down; from eight to thirteen pores between dissepiments. Fenestrules irregular, oblong, narrower at either end, twice as long as broad.

Obs. There is no fear of confusing this species with either of the other Dudley forms. Its ample size, irregular habits of growth, and large number of pores between dissepiments are its distinguishing features, and clearly mark its identity. I shall allude later on to the interest attaching to this species on account of its possessing traces of its relation with the genus *Retepora*, which, while abundant in the beds below, has not as yet been found in the Dudley beds.

Locality. Wenlock Limestone near Dudley.

Fenestella lineata, sp. nov. Plate XI. figs. 2, 2 *a*.

Sp. char. Polyzoary, base strong, cylindrical or conical, attachment solid; growth, rapidly opening outwards, forming wide funnel-shaped expansions, folded or plaited on their outer margins. Five or six inches in diameter. Interstices on the poriferous face, keeled, rounded when perfect, often angular from erosion; reverse, finely striated longitudinally: ten interstices in the space of two lines transversely. Keel fine, straight, with slight prominences; as seen when freshly or partially weathered out, it appears as a series of very regular and parallel lines, suggestive of its specific name. Dissepiments on pore-face thin, recessed, often expanding at the junction with the interstice; seven dissepiments in the space of two lines longitudinally. Pores placed on the outer surface of the polyzoarium, small, round, prominent, own diameter apart, one or two between dissepiments, and one in each angle formed by the junction of dissepiment with interstice; latter feature not always persistent, in which case there are three or four pores between dissepiments. Fenestrules on the reverse face oblong, becoming oval towards the base of the polyzoarium; on obverse face a very narrow aperture.

Obs. This species is the common form in the Upper Silurian group, and tolerably abundant in the Dudley Limestone, in this respect occupying a corresponding position to the *Fenestella plebeia*, M'Coy, among the Carboniferous species. If the nature of Lonsdale's

* King's Perm. Foss. p. 37.

species could be definitely determined, I have no doubt that most of them would be included under the head of this species. There is also an undoubted correspondence in many details between this species and the *F. rigidula*, M'Coy. The main difference, and that a serious one, is that Prof. M'Coy figures his species as having a double row of small cells on the keel, while *F. lineata* has a single row only of the prominences. I have examined many specimens of *Fenestella* from the Dudley beds without finding as yet one having the small double row of cells on the keel. The regular mode of growth, and rigid straightness of the interstice and keel, at once distinguish this species (*F. lineata*) from all others in the Silurian group.

Locality. Wenlock Limestone near Dudley.

Fenestella intermedia, sp. nov. Plate XI. figs. 3, 3 *a*.

Sp. char. Polyzoary, extreme base solid and strong, somewhat conical in shape, ultimately forming wide open expansions. Interstices on the obverse face broad, full, and rounded, having for the length of two or three fenestrules two rows of pores, succeeded by widening of the interstice and three rows of pores. This is repeated over the expansion. The three-row series of pores immediately precede the bifurcation of the interstice. Reverse, finely striated longitudinally. Width variable, alternately narrow and wide. Dissepiments thin, recessed, not expanding at junction with interstice; six dissepiments in the space of two lines longitudinally. Keel thin and fine between the two rows of pores; a corresponding line winding between each line of the three-row series of pores. Pores on the inside of the polyzoary small, circular, prominent, level with the keel, their diameter apart, three between dissepiments. Fenestrules on the poriferous face very narrow, wider on the reverse, nine in the space of two lines measured transversely.

Obs. This very fine species, which up to the present time has been strangely overlooked, except that I find it as *Fenestella patula* in the Woodwardian Museum, is by no means uncommon in the Dudley Limestone. It is met with in two very different conditions—first, when worn down, in which case the interstice is bare and cylindrical, and at certain distances on the site of the keel are two or three cell-openings. In this stage it is easily recognized by the cells occupying the place of the keel; while in the more perfect condition of the polyzoon, the poriferous face of the interstice is broad, flat, and slightly rounded at the sides, and has two or three rows of pores arranged in the manner described—not on the keel, as claimed for *F. rigidula*, M'Coy, but in the place of the keel. This, I may remark, is a unique feature among the British Fenestellidæ, no similar appearance being on record. The contrast presented between the two conditions to which I have alluded—the broad interstice with its irregular row of prominent circular pores and fine delicate keel, winding in and out between them, and fenestrules nearly obliterated by the spread of the interstice on the one hand, and a bare round branch with worn-down cell-apertures and wide fenestrules on the other—is so great that the error of making the latter into a new species might be excused; it is an instructive incident in the history of the Palæozoic Polyzoa. Taken altogether, we may claim for this species a premiership of beauty among beautiful forms.

Since writing the above I have ascertained that Hall mentions* a species (*Polypora incepta*), from the beds of the Niagara group (the Upper Silurian of North America), allied to the foregoing, only with the *Polypora*-character still more developed by having the rows of pores increasing from two to four instead of from two to three, as in *Fenestella intermedia.* In this case he assigns, rightly, I believe, the species to *Polypora*, on account of its having so many as four rows of pores on the interstice. As to the question whether *Fenestella intermedia*, with its three rows of pores, ought also to be included with *Polypora*, it may fairly be left open for consideration. It is to be borne in mind that the *Polypora*-features are not so strongly marked in it as in the other case, and that the facies generally is that of *Fenestella*; to refer it to *Polypora*, therefore, would be to ignore its leading character. It may be, and is, difficult in practice to draw the line as to where *Fenestella* ends and *Polypora* begins. The genus *Polypora* was founded by Prof. M'Coy for that division of the *Fenestella* family having more than two rows of cells on the interstice; the usual number of rows of cells in *Polypora* is from three to ten. These intermediate or compound forms, as *Polypora incepta* or *Fenestella intermedia*, were then unknown, and the difficulty as to classification had not arisen. *Fenestella intermedia* is clearly one of those connecting links between allied genera which, while they serve to unite the family as a group, are somewhat difficult to classify. Perhaps, on the whole, less violence will be done by allowing *F. intermedia* to remain with the *Fenestellæ* than by incorporating it with *Polypora*; for I believe that Hall, in speaking of his species, with its decided *Polypora*-affinities, is impressed with its strong leaning to *Fenestella*. He says:—"It is the only species of *Polypora* that has fallen under my observation in this geological period; and its characters are probably more analogous to those of *Fenestella* than are those of the Carboniferous period. *Polypora incepta* (Hall) probably shows the first departure from the character of true *Fenestella*"†. The latter position may now more truly be claimed for *Fenestella intermedia*.

Locality. Wenlock Limestone near Dudley.

I may observe that, in describing these species of *Fenestella*, I have endeavoured to do so from the best-preserved specimens obtainable, and that, after the examination of some hundreds of examples, I have not succeeded in procuring all the evidence with regard to certain details of structure that I could wish. For instance, I have no doubt that the keel of *Fenestella reteporata* possessed the usual spiny appendage. As yet I have not succeeded in tracing it. The same remark will apply to other details. A general caution is

* Hall's Pal. New York, vol. ii. pl. 40 D. fig. 5. † *Ibid.* p. 167.

here requisite. The altered appearance presented by a worn-down specimen of *Fenestella* from the Dudley Limestone is very great; this will necessitate certain allowances when the species under examination are, as is usually the case, much weathered and denuded. The cell-apertures, in good specimens, are small and round, and quite their diameter apart. When worn down, the cell-aperture is large, and the intermediate spaces between the cells nearly obliterated or they have only the body-wall between them. Again, in the more perfect examples the obverse face of the interstice is full and rounded, with a prominent keel; when worn down, the sides of the interstice have a sharp angular face—a great contrast to what it had been. In the one case the fenestrules may be narrow originally, and become altered to wide by erosion. So, too, with the reverse face; in *Fenestella*-growth the lines of construction give rise to strong striations on the reverse side of the polyzoary, which, however, in the Silurian species, are seldom seen, as the structure is generally worn down and smooth.

Certain features would be constant in the Fenestellidæ (I allude to the keel, the small circular pore, and the striations on the reverse) were it not that they had been worn away from a variety of causes.

It may be interesting here to compare polyzoal life, so far as concerns the Fenestellidæ, at the two great horizons of its growth—the Silurian and Carboniferous, the early and late Palæozoic. The Lower Silurian forms have special interest, on account of their apparent relationship with the Graptolites, which they seem to replace in the higher series. Unfortunately the material available for comparison is so scanty, and the special organs so imperfectly preserved, that the affinities between the genera cannot well be ascertained, at least for the present. No such reasons, however, exist to hinder the comparison between the species found in the Upper Silurian Limestone and those of the Carboniferous Limestone. The result of the comparison is that we discover that the Silurian forms have a distinct *facies* of their own, being often more minute in structural details and altogether different in the general outline of their growth, at the same time having the true and marked features of *Fenestella*-growth. To indicate some of the peculiarities of the Silurian Fenestellidæ, I may mention the strong conical structure, often solid and slightly bulbous at the extreme point of the base, of *Fenestella lineata*; this would seem to indicate a species capable of being firmly attached by its base, and adapted to resist the action of powerful currents of water. A glance at Lonsdale's drawings of the Fenestellidæ will show how frequently they were possessed of this strong basal attachment; we have nothing, strictly speaking, among the Carboniferous forms to compare with it, with one partial exception—the *Fenestella membranacea* (Phil.). So it comes to this, that the strong conical base of the Silurian *Fenestella* is now only partially seen in one of the Carboniferous species. The leading type in the polyzoary of the Carboniferous Fenestellidæ is a flat expansion, slightly depressed in the centre, which formed its point of attachment; while numerous rootlets from various parts of the structure, but more especially from near the base, served to secure it in position, which would seem to have been the sides of projecting rocks or suitable exposures. Of these non-poriferous rootlets, which are quite a feature in the Carboniferous Fenestellidæ, and notably so in *Fenestella plebeia*, M'Coy, we have no trace whatever in the Silurian species. We may notice the beginning of the Carboniferous type of polyzoarium in the wide cup-like expansion of one of Lonsdale's forms, *Retepora infundibulum*. The resemblance here is all the more complete, since the poriferous face is on the inside of the polyzoary, as in the Carboniferous species. Again, we may compare the position of the poriferous face. In *Fenestella lineata*, a prominent and leading species among the Silurians, it is on the outside of the polyzoarium; in all the Carboniferous species it is on the inner side of the same. So, too, we may notice that the prevailing Silurian species are all much smaller than the Carboniferous. Our knowledge of the cell-character in the Silurian *Fenestellæ* is necessarily limited; but this we may say, that as yet no material difference has been noticed, either as to cell-structure or internal arrangement, as compared with the Carboniferous. The angular knife-edged character of the interstice in Silurian species, often alluded to by Hall * and Lonsdale † as a distinguishing mark, is the result of denuding agencies; the original condition may often be seen by careful searching in some fold or protected part of the polyzoarium, when it will be seen that the obverse face was full and rounded, with projecting circular pores, similar to the Carboniferous types.

There are, besides what I have mentioned, several interesting individual features which may be noticed. For instance, in the lower horizon of the Bala beds *Retepora* is abundant and *Fenestella* scarce; while in the Dudley Limestone *Fenestella* is abundant and *Retepora* absent, so far as I am aware. The interesting point here is that some of the *Fenestellæ* in the Dudley beds, in which as yet we have no record of *Retepora* having been found, have strong affinities to *Retepora* or, more strictly speaking, *Polypora*, M'Coy; for the genus *Polypora* is really the connecting-link between *Retepora* and *Fenestella*, combining, as it does, many of the features of either group. It is not too much to say of *Fenestella intermedia* that there is on the polyzoary an alternate interchange of polyzoal features; that on a branch may be seen for a short distance the double row of cells divided by the customary keel, succeeded by three rows of cells and no keel strictly speaking; this interchange of character is persistent over the expansion. Thus we have here typical *Fenestella* and typical *Polypora*, not only on one branch, but on the whole—an alternation of character, *Fenestella* and *Polypora*, that, to say the least, is very interesting, as showing the connexion between *Retepora* and *Fenestella*. I have not met with any like features among the Carboniferous species, and therefore conclude that they are confined to the Silurian types.

Another species having evident affinities with *Retepora*, even more

* Hall's Pal. New York, vol. ii. p. 50. † Murch. Sil. Syst. p. 678.

marked than the preceding, is the species I have described as *Fenestella reteporata.* In size and outline the species is decidedly *Retepora* in character. It has none of the straight lines and general uniformity of structure which are so characteristic a feature of the Fenestellidæ. Instead of this we have irregular interstices, and fenestrules of all shapes. The dissepiments, however, show most markedly the character of *Retepora.* Not on all, but on some of them, it is most difficult to distinguish between the dissepiment and interstice, so near do they approach in character the anastomosis of the branch, which is the distinguishing feature in *Retepora.* The likeness is further assisted by the occurrence here and there of cells on the dissepiments. These latter features are not so marked or persistent as to cause any doubt as to its being a true *Fenestella,* while they indicate clearly the direction whence the disturbing influence came.

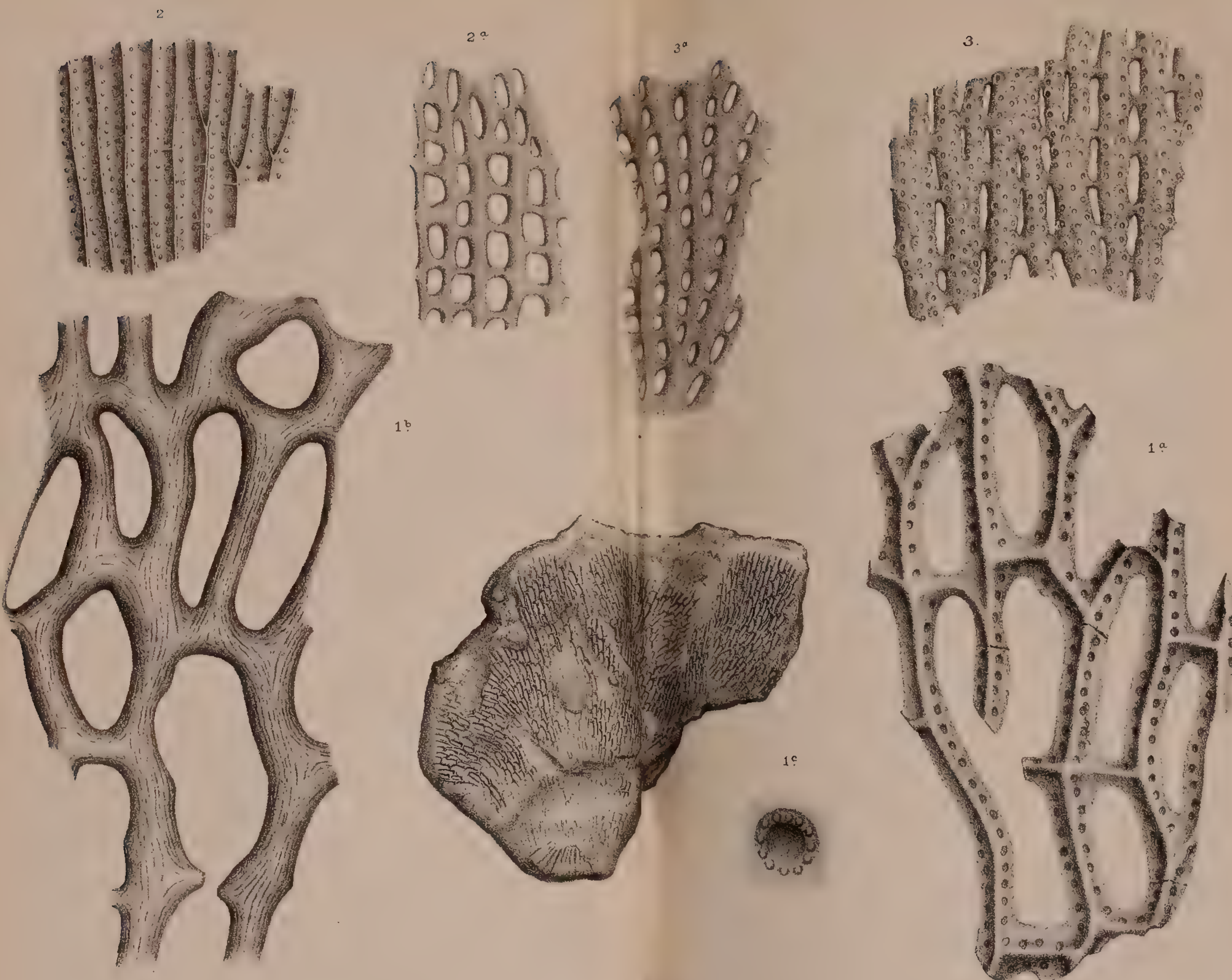
I desire to express my obligations to Professor Hughes of Cambridge, and also to the officers of the Geological Society, for much assistance in examining the type specimens under their charge.

EXPLANATION OF PLATE XI.

Fig. 1. *Fenestella reteporata,* Shrubsole. A specimen of the natural size in the Woodwardian Museum, Cambridge.
1 *a.* Obverse view, × 12 diameters.
1 *b.* Reverse view, × 12 diameters.
1 *c.* Ring of pits, within cell-mouth.
2. *Fenestella lineata,* Shrubsole. Portion of obverse surface, × 12 diameters. Only partially weathered from matrix.
2 *a.* Reverse face, × 12 diameters.
3. *Fenestella intermedia,* Shrubsole. From the cabinet of G. H. Morton, F.G.S. Portion of obverse surface, × 12 diameters.
3 *a.* Reverse face, × 12 diameters.

Discussion.

The President remarked upon the value of this communication, and upon the service done by the author in reducing the number of supposed species of Polyzoa in the Carboniferous and Upper Silurian rocks.



SILURIAN FENESTELLÆ.

C. Berjeau del et lith

Mintern Bros imp

17. *On the* Geological Relations *of the* Rocks *of the* South of Ireland *to those of* North Devon *and other British and Continental Districts.* By Professor Edward Hull, M.A., LL.D., F.R.S., &c., Director of the Geological Survey of Ireland. (Read March 10, 1880.)

I. Introduction.

Having in a former communication to this Society* endeavoured to prove that the great series of purple and green grits and slates which form the southern highlands of Ireland belong to the Uppermost Silurian period, and that between them and the succeeding beds of the Old Red Sandstone there occurs everywhere a wide hiatus (a gap of unrepresented geological time), indicated not only by visible unconformities but also by absence of intervening beds at various points, it now becomes desirable to inquire, and, if possible, to determine what formations in other districts may be supposed to fill up the hiatus above referred to, and then, having determined this point, to see what inferences may be drawn concerning the physical geology of the regions referred to at the various stages indicated both by the presence and the absence of consecutive strata.

This inquiry naturally leads one to cast a glance at the neighbouring coasts of England and Wales as the districts where light may be looked for on these questions; and I propose in the following pages to make a comparison of the series of beds in both countries, namely the South of Ireland and North Devon, and adjoining districts north of the Severn†. It will also be desirable, with a view to a fuller investigation, to refer, when necessary, to the Devonian and Carboniferous series as it occurs in Belgium and Scotland, and to see how far it is comparable with, and sustains our observations of, the Devonshire section.

Views of previous Authors.

Previous Investigations.—It is almost unnecessary for me to observe that there are few districts of the British Isles which have received more careful scrutiny, and are the subjects of more elaborate memoirs, than those of North Devon and West Somersetshire, and I am therefore happily relieved from the necessity of any attempt at lengthened description. The geological literature of the district has been carefully summarized by Mr. Etheridge in his

* "On the Geological Age of the Rocks forming the Southern Highlands of Ireland, generally known as the Dingle Beds and Glengariff Grits and Slates," Quart. Journ. Geol. Soc. vol. xxxv. p. 699 (1879). I find that Prof. Ralph Tate states, with much precision, that the Dingle beds are the equivalents of the "Tilestones of England, South Wales," &c. ('Historical Geology,' Weale's series, p. 72). I was unaware of this when my former paper was published.

† I confine my observations to North Devon, as it furnishes the key to the structure of South Devon and adjoining parts.

elaborate paper "On the Physical Structure of West Somerset and North Devon"*, from which I shall have occasion to quote rather frequently; and the reader may be referred to it for an account of what others have done in this field of inquiry. This paper renders any attempt of the same kind altogether useless.

It is also scarcely necessary for me to do more than to allude to the controversy which called forth Mr. Etheridge's exhaustive paper. We all recollect with what ardour and ability my friend and predecessor, the late Professor Jukes, endeavoured (as we may say) to obliterate the great group of marine beds established by Murchison and Sedgwick under the name of "Devonian" from off the geological map of the British Isles and of Western Europe. If *success had been possible, he ought to have succeeded*; but for myself, I feel satisfied that success was impossible, because the evidence, both physical and palæontological, in favour of the views of the founders of the "Devonian System" is overwhelming; and if any doubt on this point remained after Professor Jukes's papers had seen the light, it has been completely removed by the essay of Mr. Etheridge, supplemented, in the same volume of our Journal, by that of a careful and accurate observer, who for years had studied these rocks on the spot, Mr. Townshend M. Hall†. A recent visit to the district confirms me in the belief that between the "Foreland Grits" and the Carboniferous Limestone there is a great and consecutive series of marine beds, and that it is comparable (with certain modifications) to the Belgian section of the same rocks.

II. Statement of the case.

Perhaps the simplest way of presenting my subject will be to state the case in a series of separate propositions or theses, and then to offer for consideration the evidence upon which they are based. Considered in the order in which I propose to treat them, they may thus be stated.

First. Having, in the paper already referred to, shown that between the Glengariff grits and slates (which, for brevity, I shall henceforth call "the Glengariff beds") and the succeeding formations, either of Old Red Sandstone or Carboniferous age, there is a wide hiatus of unrepresented time, I shall endeavour to show that this is filled up in the south and south-west of England and in Belgium by the great 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.

Secondly. That, consequently, 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.

* Quart. Journ. Geol. Soc. vol. xxiii. p. 568.

† "On the Relative Distribution of Fossils in the North-Devon Series." In a recent joint paper by Messrs. Champernowne and Ussher, "On three traverses made in North Devon," they state that their observations go to confirm Mr. Etheridge's views.

Thirdly. I shall offer some observations on the points of analogy and contrast between the Old Red Sandstone of the South of Ireland and its representatives in North Devon, Belgium, and Scotland.

Fourthly. I shall endeavour to show the true position in the region of "Siluria" of the Old Red Sandstone on the one hand, and the equivalents of the Glengariff beds on the other, and indicate the geological position of the "Cornstone" group in the Devonian series, and conclude with some general observations.

III. Carboniferous and Old Red Series.

Descending Series in the South of Ireland and N. Devon.—In order to prepare the way for the consideration of the first thesis, it is necessary to give a brief description of the descending series immediately underlying the Carboniferous Limestone in the districts of the South of Ireland and North Devon, and by comparing them together to obtain a clear idea of the position of the hiatus as it occurs in the former district. In this comparison my views are happily in unison with those of the late Professor Jukes*, the late Mr. Salter†, and (I believe I may also say) of Mr. Champernowne, F.G.S., who has devoted so much time to the study of the rocks of Devonshire‡. The only objections which can with any plausibility be urged are those based on the occurrence of fossils in the one district not found in the other; but all such objections seem to me to disappear when the important differences which were prevalent in the physical geography of these districts respectively are taken into consideration.

The descending series of beds below the Carboniferous Limestone in both districts having been frequently and fully described, only a brief summary is here necessary. I shall commence with that in the South of Ireland.

Descending Series, South of Ireland.

Carboniferous Limestone. Coralline, crinoidal, and shelly limestone; sometimes cleaved (thinning towards the south-west).

Carboniferous Slate (*top beds*). Black slate with calcareous bands full of fossils (2). Black and grey slate, with few fossils (1).

Coomhola Grit. Grey and olive-green slates and tiles with fine-grained hard grey grits, with marine shells and some plants, the whole having a maximum thickness in Co. Cork of 5000 feet§.

Old Red Sandstone‖. (*a*) "Kiltorcan beds;" fine-grained, yellowish,

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* "On the Carboniferous Slate," &c., Quart. Journ. Geol. Soc. vol. xxii. p. 348, &c.

† *Ibid.* vol. xix. p. 474.

‡ "The Devonian Question," Geol. Mag. March 1879.

§ Jukes and Geikie, Man. Geol. p. 586.

‖ The Old Red Sandstone with the Kiltorcan beds at the top and the conglomerate at the base is the "Upper Old Red Sandstone" of Scottish geologists, which "graduates upwards into the Lower Carboniferous Sandstones," as stated by Professor Geikie ("The Old Red Sandstone of Western Europe," Trans. Roy. Soc. Edinb. vol. xxviii.); the "Lower Old Red Sandstone and Conglomerates" of Lesmahago and the Pentlands is doubtless the representative of the Glengariff or Dingle beds, as suggested by Prof. Geikie; but the question remains, Are they not really of uppermost Silurian age?

greenish, and reddish sandstones and shales, with fish (*Asterolepis*, *Bothriolepis*, *Glyptolepis*, *Coccosteus*, and *Pterichthys*), also *Anodonta Jukesii* and plants (*Adiantites*, &c.): (*b*) the above passing down into massive reddish-brown and purple soft sandstone with a conglomerate base*, the whole about 3000 feet thick.

The basal conglomerate of the Old Red Sandstone is everywhere unconformable to the rocks on which it rests over the South of Ireland, as frequently insisted on by the late Sir R. Griffith †. This unconformity is equally conspicuous, whether it refers to the contact of the conglomerate with the Uppermost Silurian beds in the promontory of Dingle, or to the Lower Silurian beds of the Comeragh or Galtee Mountains. On the other hand, all the beds from this conglomerate upwards into the Carboniferous Limestone are apparently in perfect conformity with each other, notwithstanding the change from the apparently freshwater "Kiltorcan beds" into the marine "Coomhola-Grit series" which succeeds to them. The hiatus in the South of Ireland is therefore at the base of the Old Red Conglomerate.

IV. Division between the Carboniferous and Old Red Sandstone Formations.

A recent author has included the Old Red Sandstone of the south of Ireland in the Carboniferous group, on the ground that "in no place in Ireland has it a defined upper boundary, one group graduating into the other"‡. Although this view finds some support, if the purely stratigraphical relations of the two series alone be regarded, yet it seems to be untenable upon palæontological and physical considerations, to which sufficient weight has not been allowed by the author above quoted. In the first place, the occurrence of *Anodonta*, together with the absence of any traces of marine organisms, seems to point conclusively to the lacustrine origin of the upper beds at least ("Kiltorcan beds") of the Old Red Sandstone; on the other hand, the moment we pass upwards into the slates and grits of the overlying "Coomhola series," we are met by abundant evidences of the prevalence of marine conditions in the occurrence of such genera as *Avicula*, *Cucullæa*, *Modiola*, *Mytilus*, *Rhynchonella*, and *Spirifera*, and other forms which connect these beds with the Carboniferous system.

Again, the occurrence in the Kiltorcan beds of the remains of fish, belonging to recognized Old Red Sandstone forms, both in Scotland and elsewhere, such as *Asterolepis*, *Bothriolepis*, *Glyptolepis*, *Coccosteus*, and *Pterichthys*, none of which ascend into the Carboniferous series of other districts, or into the Carboniferous-Slate series of Ireland, places the relations of these beds to the Old Red Sandstone beyond question. In fact, it is abundantly clear that lacustrine

* This great conglomerate is well shown in the banks of the river Suir at Waterford, and the escarpments of the Comeragh Mountains in Co. Waterford, and of Caher-con-ree in the Dingle promontory. See Section I. sheet 13, of the Sections of the Geol. Surv. Ireland, &c.; also Jukes, Quart. Journ. Geol. Soc. vol. xxii. p. 328.

† Journ. Geol. Soc. Dubl. vol. viii. *passim*.

‡ Kinahan, 'Geology of Ireland,' p. 63.

conditions prevailed over the area of the South of Ireland during the deposition of these beds, and that thus by their fossils and physical relations they correspond with the deposits of those great inland lakes which modern geologists, such as Mr. Godwin-Austen and Professor Ramsay, regard as the basins of deposit for the Old Red Sandstone*.

This distinction between the lacustrine fauna of the Old Red Sandstone and the marine fauna of the succeeding beds has been noticed by Prof. Haughton as well as Mr. Baily, and my late colleagues Messrs. Jukes and Salter. It seems to me that in this distinction we have a well-defined ground of classification, which is also concurrent with slight, but definite, distinctions in the lithological characters of the beds themselves over considerable areas.

In accordance, therefore, with the above views supported by so strong a body of evidence, I shall continue to regard the line of division between the Old Red Sandstone and the Carboniferous series as traceable at the base of the Coomhola-grit series, or at the top of the Kiltorcan beds with *Anodonta* and *Palæopteris*. From these premises I now pass on to describe briefly the corresponding series in North Devon, as generally recognized.

V. Descending Series, North Devon and W. Somerset.†

(Carboniferous and Upper Devonian.)

Carboniferous Limestone. (Benn Quarry.) Dark earthy carbonaceous limestone in regular beds (*Posidonomya Becheri*).

Carboniferous-Slate Series. (Barnstaple beds.) Top beds, dark schists (contorted) resting on light-grey slates, with calcareous nodules. *Cyathocrinus distans* &c. seen at Barnstaple station.

"*Pilton beds*" (Phillips). Slates of a purplish or greyish tint, Brachiopods, crinoidal stems, and a small Crustacean (*Phacops latifrons*); thin intermittent bands of limestone are common, and are highly fossiliferous ‡.

"*Cucullæa*-zone" (Hall), also called "Marwood Beds", by Jukes and Salter. Light grey and olive-green slates with bands of hard grit, and calcareo-ferruginous beds with three species of *Cucullæa*. These beds are shown in the railway-cutting north of Braunton Church.

Below the above are found (east of the village of Upcot) yellowish and greenish flags and shales, passing downwards into purple sandy shales and grits, sometimes of a pale green colour, similar in appearance to the "Kiltorcan beds."

"*Pickwell-Down Sandstone.*" Purple and red sandstones with thin shaly bands in the upper part; greyish grits, sometimes massive, with thin shaly bands, in the lower; no fossils; the bands of shale, though requiring to be mentioned, are quite unimportant.

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* R. Godwin-Austen, Quart. Journ. Geol. Soc. vol. xii. p. 51; Prof. A. C. Ramsay, *ibid.* vol. xxvii. p. 243; Prof. Geikie, Trans. Roy. Soc. Edinb. vol. xxviii. part 1.

† Descriptions of these beds will be found in the writings of several authors; but I give those written down by myself during my visit in the autumn of 1879, under the friendly guidance of Mr. Townshend Hall and Mr. Ussher.

‡ Hall, Quart. Journ. Geol. Soc. vol. xxiii. 374. According to this author, the Pilton beds form the uppermost member of the Devonian series. This view was also maintained by the late Mr. Salter, who, however, recognized the presence of some forms found in the Lower Carboniferous series of the S. of Ireland (*ibid.* vol. xix. p. 482).

That the "Pilton" and "*Cucullæa-*" or "Marwood" beds are the equivalents of the "Coomhola grits and slates" of the South of Ireland, and therefore (as shown above) of Lower Carboniferous age, is evinced by a community of species to a large extent. Of these the following have been kindly determined for me by Mr. Baily, F.G.S., from the collections of the Irish Geological Survey:—

Species common to the Pilton and Marwood beds of Devonshire, and to the Coomhola beds of the South of Ireland.

Brachiopoda: *Chonetes hardrensis*, *Rhynchonella pleurodon*, *Streptorhynchus crenistria*, *Strophomena rhomboidalis*, var. *analoga*, *Productus scabriculus*, *Spirifer Urii*, *Lingula squamiformis*.

Conchifera: *Cucullæa Hardingii*, *C. trapezium*, *C. amygdalina*, *Avicula damnoniensis*.

The great majority of the forms range up into the Carboniferous Slate, and some into the Carboniferous Limestone, and clearly prove the strong Carboniferous, rather than Devonian, affinities of the Pilton and Marwood beds.

VI. Relations between the Irish and Devonshire Sections.

Having thus far described the general descending series of both districts, it is necessary to pause at this point, because the analogy between the two series here ceases altogether; for, as I believe, and as I hope to be able to demonstrate, the underlying Middle and Lower Devonian series of Devonshire is entirely unrepresented in the Irish area, nor do we again begin to correlate the beds till we arrive at the basement formation of all, namely, "The Foreland Beds."

With regard, however, to the series above described, there is a remarkable concurrence of opinion between the most eminent geologists who have made the comparison, that all the beds from the base of the Carboniferous Limestone down to the top of the Pickwell-Down Sandstone are representatives of the Lower Carboniferous Slate and Coomhola grit of the South of Ireland.

This view was clearly put forward by the Rev. Dr. Haughton, F.R.S., as far back as 1855, in a paper read before the Geological Society of Dublin*, and was laid down and defended, both on stratigraphical and palæontological grounds, by the late Mr. Salter in the year 1863†. Mr. Salter shows that, while the Carboniferous Slate and Barnstaple beds are characterized essentially by Carboniferous forms, the Pilton and Marwood beds (*Cucullæa*-zone) contain some Upper Devonian forms, many of which are found in the Coomhola-grit series of the Co. Cork.

The correlation thus established by Haughton and Salter is, in the main, the same as that subsequently adopted by Jukes ‡ and

* "On the Evidence afforded by Fossil Plants as to the boundary line between the Devonian and Carboniferous Rocks," Journ. Geol. Soc. Dubl. vol. vi. p. 227.

† "On the Upper Old Red Sandstone and Upper Devonian Rocks," Quart. Journ. Geol. Soc. vol. xix. pp. 488 &c.

‡ *Suprà cit.* p. 345 *et seq.*

Etheridge *. Both of these authors agree in considering the Barnstaple, Pilton, and Baggy (or Marwood) beds as on the same general geological horizon as the Carboniferous Slate and Coomhola Grit, and, moreover, the Pickwell-Down Sandstone as the representative of the (Upper) Old Red Sandstone of the South of Ireland. For my own part, I think it is impossible to come to any other conclusion from a consideration both of their stratigraphical position, their lithological constitution, and the organisms they respectively contain. Considering the geographical distance between the south-west of Cork, in which the Coomhola beds are most fully developed, and North Devon, the general similarity on all these points is remarkably striking, and the differences are only such as might be expected to arise over tracts of similar extent at the present day.

The points of greatest difference between the faunas of the two areas seem to be, first, the occurrence of a few Upper Devonian species peculiar to the Pilton beds, such as *Phacops latifrons*, not found in Ireland ; and, secondly, the occurrence of the lacustrine or freshwater *Anodonta Jukesii*, which has not yet been found in Devonshire, in the upper part of the Old Red Sandstone in Ireland.

(1) At the time when it was supposed that there was "an unbroken sequence" from the Glengariff beds of the South of Ireland into the Coomhola grit and Carboniferous Slate, and that the Glengariff beds were the representatives of the Middle and Lower Devonian series †, it was very difficult indeed, if not impossible, to account for many of the palæontological distinctions between the Upper Devonian beds of North Devon and the Lower Carboniferous beds of the South of Ireland; but when it is known that (as I have endeavoured to prove in the paper already referred to ‡) there is everywhere a great hiatus between the Glengariff beds and the succeeding series, whether Old Red or Carboniferous in Ireland, while there is a continuous ascending series in Devonshire, the causes of these differences at once become apparent. In Devonshire, many of the species belonging to the (so-called) Upper Devonian (Pilton beds) come up from the underlying Middle Devonian beds, having migrated for some distance eastwards or southwards, and undergone modification of form during the stage of the Pickwell-Down Sandstone, and then returned when the conditions became favourable for their sustenance and vitality. But no such ascent was possible in the Irish area, and all the species (about 47 out of 56) which are found in the Lower Carboniferous beds of Ireland and in those of the "Upper Devonian" beds of Devonshire were derived by migration from the Devonshire area. The general conclusion from all this is that we must eliminate the Marwood and Pilton beds from the Upper Devonian, and place them in the Lower Carboniferous series.

(2) The occurrence of *Anodonta*. Certain strata lying just below the "*Cucullæa*-zone" and above the Pickwell-Down Sandstones, similar in appearance, as well as in position, to the Kiltorcan beds of the South of Ireland, may possibly yet be found to yield this re-

* *Suprà cit.* table xii. p. 698. † See Etheridge's table, *loc. cit.*
‡ Quart. Journ. Geol. Soc. vol. xxxv. p. 699.

markable freshwater mussel. Up to this time, however, it has not been discovered in Devonshire*.

This is not surprising when the relations of the strata in each district are considered. In the South of Ireland the Old Red Sandstone deposited along the slopes of subsiding lands†, giving rise to the bed of shingle now forming its conglomerate base, was favourably situated for the formation of lucustrine conditions. The formation is in all probability the deposit of a lake, the waters of which were inhabited by the peculiar fishes of the period as well as by this large freshwater mussel. It may have been otherwise, however, with the representative beds in the Devonian area. The Pickwell-Down Sandstone is here underlain, as well as overlain, by essentially marine beds, those of Ilfracombe and Mortehoe ‡; and it is possible that the lacustrine conditions of the South of Ireland gave place to marine conditions over the Devonian area during the same time. This view finds support in the fact (which I will again advert to) that the representative beds in Belgium (Psammites du Condroz) contain marine fossils.

(3) It will now be apparent why the Pickwell-Down Sandstone, though the representative of the Old Red Conglomerate of the South of Ireland, is not itself a conglomerate. The conglomerate of Ireland was formed along the flanks, and over the edges, of older unconformable beds; but this was not so in the case of its representative. Hence the difference of mode of accumulation and in composition. Reduced to a tabulated form, then, it may be taken as generally agreed that the following are the representative beds of the Lower Carboniferous and Upper Devonian, or Old Red Sandstone, in each district:—

Representative Beds.

	South of Ireland.	*North Devon.*
Lower Carboniferous beds.	Carboniferous Limestone.	Carboniferous Limestone.
	Carboniferous Slate.	Barnstaple beds.
	Coomhola Grit and Slate (passage-beds).	Pilton beds. Baggy and Marwood beds (*Cucullæa*-zone).
Old Red Sandstone or Upper Devonian.	Kiltorcan beds.	Upcot beds?
	Old Red Sandstone and Conglomerate.	Pickwell-Down Sandstone.

VII. Middle and Lower Devonian Beds.

The great series of marine fossiliferous strata which underlies the Pickwell-Down Sandstone in North Devon, and constitutes "the Middle and Lower Devonian" series of Sedgwick and Murchison § not being represented (except perhaps in its lowest part) in the

* *Anodonta* has been found in Northumberland by Mr. Lebour, F.G.S., in beds probably corresponding in position to the Kiltorcan beds of the South of Ireland.

† As I have shown in my former paper *suprà cit.*

‡ The Mortehoe slates have not yielded fossils. The absence of calcareous bands and the micaceous character of the beds are indicative of the absence of fossils; but they may be regarded as the upper members of the Ilfracombe series.

§ Rep. Brit. Assoc. 1836; 'Siluria,' 4th edit. p. 272.

South of Ireland, only requires a brief notice here. These beds having been repeatedly described by previous writers, from the Rev. D. Williams * and Mr. Weaver † down to Messrs. Townshend Hall ‡ and Etheridge ‡ in more recent times, I here give descriptions taken chiefly from my own note-book. The beds are described in descending order:—

(1) *Mortehoe Slates.* Glossy micaceous slates, uniform in texture, and such as might have originated from the waste of gneiss or mica-schist: unfossiliferous.

(2) *Ilfracombe beds.* A variable series of grey slates and thin grits, containing numerous bands of blue earthy limestone ("*Stringocephalus*-limestone"), chiefly in the lower part. These beds are highly fossiliferous, containing polyzoa, corals, and mollusca in abundance.

(3) *Hangman Grits* (Martinhoe beds of T. M. Hall). Hard, fine-grained, red, purple, and grey grits with bands of slate rising from below the Ilfracombe slates at Combe-Martin Bay. These beds, like those of the Pickwell-Down Sandstones, form high tablelands or downs, traversed by deep dells leading down to the sea.

(4) *Lynton Slates.* Greyish sandy slates and fine grits, cleaved, passing down into calcareous banded slates and earthy limestones, highly fossiliferous. These beds break off into scarped cliffs, ridges, and tors along well developed planes of jointage. Corals, polyzoa, crinoids, spirifers &c., are abundant.

(5) *Foreland Grits.* Massive coarse- and fine-grained grey, purple, and green grits, with bands of schist. Pebbles of quartz, quartzite, and slate sometimes occur. The beds are contorted, and their base is nowhere visible §. Fucoid and linear plant-remains occur, resembling those from the Glengariff beds of Ireland.

Fossils.—The Middle Devonian; or Ilfracombe beds have yielded, according to Mr. Etheridge, 73 known forms, of which about 20 come from the Lower Devonian or Lynton beds; but only three forms from the Lower, and 28 from the Middle Devonian beds are found in the Carboniferous beds generally ||, and not a single form out of either the Lower or Middle divisions has been discovered in the Glengariff grits or slates of Ireland, with which they have been correlated by some authors.

Thickness of beds.—A careful estimate of the thickness of the Devonian beds of North Devon has been made by the Rev. Dr. Haughton, which, as being the most recent, I here insert, though the question of thickness of strata is not one materially affecting the subject under consideration. Dr. Haughton's estimate ¶ is as follows:—

(*a*) From the lowest beds at Lynmouth, occupying the summit of the great anticlinal arch, up to the Ilfracombe marine limestone, 4400 feet.

(*b*) From the Ilfracombe limestone to the *Cucullæa*- and plant-beds

* Rep. Brit. Assoc. 1839, Trans. of Sections, p. 95.

† Proc. Geol. Soc. Lond. vol. ii. pp. 589, 590.

‡ *Suprà cit.* See also De la Beche, 'Rep. Devon. Corn. & Somer.' plate 3, &c.

§ See De la Beche's section, plate 3, *suprà cit.* In placing the Foreland Grits at the base of the Lower Devonian, I adopt at this stage the prevalent view. Further on it will be seen that there is reason for supposing they form the connecting link between the Devonian and Silurian series.

|| *Suprà cit.* pp. 674, 675.

¶ Journ. Roy. Geol. Soc. Ireland, vol. v. (new ser.) pp. 126, 127.

of Baggy Point and Marwood, 5200 feet. In all of Devonian beds proper, 9600 feet.

(*c*) From the *Cucullæa-* and plant-beds to the flinty calcareous slates of Barnstaple, 2200 feet.

Absence of the Middle and Lower Devonian Series in Ireland.

After the description above given of the Middle and Lower Devonian beds of North Devon, it may be asked, Where is such a group to be found in the South of Ireland?

According to the views I entertain, they are not represented at all. As I have already shown, the Old Red Conglomerate of the South of Ireland has no immediate predecessor in the formations of that country. The hiatus and unconformity which are so marked between the Glengariff beds on the one hand and the Old Red or Lower Carboniferous beds on the other * show that certain strata are absent over this area; and if the correlation I have indicated above between the Devonshire and Irish sections be correct, then it follows *that the Middle and Lower Devonian beds exactly occupy the place of the missing strata in the South of Ireland.* Any attempt therefore to correlate these beds with the Glengariff or Dingle series appears to me an error; and it is not till we reach the basement-beds of the whole series of North Devon, viz. the Foreland grits and slates, that we have any real representatives of the Glengariff beds, which, on grounds already stated, I consider to be of Upper Silurian age †.

The view which I now venture to offer for explaining the relations of the Devonian series to the formations of the South of Ireland seems to meet the difficulties which have hitherto beset this problem ‡. I have already shown that in the South of Ireland the succession of the strata was interrupted after the formation of the Glengariff or Dingle beds. Up to this, from the base of the Upper Silurian series, throughout the Wenlock, Ludlow, and Gengariff stages, deposition went on uninterruptedly; and then came cessation of deposition, elevation of the sea-bed, and denudation. Everywhere between the Glengariff beds and those which succeed them, whether Old Red Conglomerate, Kiltorcan flags, or Lower Carboniferous grits and slates, there occurs a *break in succession of strata*, an *hiatus*, indicative of land-conditions and the absence of certain strata for which we are obliged to look elsewhere. Now, as all the beds from the Carboniferous Limestone to the Pickwell-Down sandstone inclusive, are clearly represented in the South of Ireland by the Carboniferous Limestone, the Carboniferous Slate, the Coomhola Grit, and the Old Red Sandstone, it is clear that the Middle and Lower Devonian beds of Devonshire are in reality the missing strata. But before pursuing this subject further I wish to show

* The relations of these beds are illustrated by a diagrammatic plan and sections in my paper above quoted, p. 713.

† *Ibid.* pp. 703, 715–718, &c.

‡ These views were first briefly sketched out in a paper published in the 'Geological Magazine,' Dec. 1878, and have received the approval of Mr. A. Champernowne, F.G.S., in the Geol. Mag., March 1879.

that there is reason for believing that the Glengariff beds really *have* some representatives in the Devonshire section, and this in the very basement beds of the whole series of strata represented in North Devon, namely the Foreland grits and slates.

VIII. The Foreland Grits, possible Representatives, in part, of the Glengariff Beds.

No one who compares the Foreland with the Glengariff beds can fail to admit the strong resemblance they bear to each other, except for the greater predominance of grits in the former*. The section, however, of the Foreland beds is imperfect; the base is nowhere visible, as shown by De la Beche; but as far as it extends, the resemblance is almost complete. I have already described these beds, and remarked on the resemblance of the plant-remains they contain to those of the Glengariff beds. All things considered, we cannot be far wrong in supposing that the Glengariff beds *at the top* of the Silurian series of the one country are on, or about, the same geological horizon as the *basement-beds* of the Lower Devonian series of the adjoining country. In each case they may be regarded as the connecting links between the Silurian and Devonian groups, and therefore as occupying a nearly similar, if not identical, stratigraphical position. If this be admitted, we are now in a position to complete the entire geological history for both countries, each furnishing to the other the missing links in the geological chain, thus enabling us to understand both the analogies and distinctions in the physical events of the great period which intervened between the Silurian and Carboniferous epochs.

I have endeavoured to represent in the annexed Table (p. 266) the geological series of the south of Ireland and North Devon; and to avoid repetition I have placed in juxtaposition the representative series in Belgium, to which I will refer subsequently.

As regards South Devon, I have nothing to add to what has already been written by various authors. The North-Devon section, so complete and clearly laid open, is admittedly the key to that of South Devon†. As Mr. Etheridge has shown, the Middle Devonian limestone of Newton Abbot and Plymouth is not only more fully developed as a limestone formation than its representative at Ilfracombe &c., but it contains a much larger assemblage of marine fossils, while there are grounds for believing that the representatives of the Upper Devonian beds are less clearly represented, or are concealed by faults along the margin of the Carboniferous area, or, finally, are cut out by the granitic intrusions. To determine these points fully will require a very careful and detailed survey‡.

* Prof. Jukes describes them as "thick massive grits of green and red colours with purple slates, . . . the whole being similar to many parts of the Old Red Sandstone of the south-western portion of Iceland," meaning thereby the Glengariff beds.—*Additional Notes, &c.* p. 9 (1867).

† Except that the "Upper Devonian Limestone" with *Goniatites* at Chudleigh, described by Dr. H. Holl and Prof. Römer, seems to be unrepresented in North Devon (see Geol. Mag., April 1880).

‡ Dr. Holl considers that in South Devon there is an unconformity between the base of the Culm-measures and the underlying Devonian rocks.

Representative Series in the South of Ireland, North Devon, and Belgium.

	South of Ireland.	North Devon.	Belgium.
Lower Carboniferous Series.	1. Carboniferous Limestone. 2. Lower Carboniferous Slate. 3. Coomhola Grit Series (Passage-beds).	1. Carboniferous Limestone. 2. Barnstaple Slates. 3. Pilton, Baggy, and Marwood Beds.	Carboniferous Limestone. Grey and reddish Shales and Grits.
Upper Old Red Sandstone (Ireland and Scotland), or Upper Devonian (Belgium and Continent) in part.	1. Kiltorcan beds with *Anodonta.* 2. Old Red Sandstone and Conglomerate at base.	1. Upcot beds ? 2. Pickwell-down Sandstone.	"Psammite du Condroz."
Do. in part.	....	1. Mortehoe Slates.	"Schistes de Famennes." "Calcaire de Frasne" (*Spirifera disjuncta*).
Middle Devonian Series.	*Hiatus.* No Representatives.	1. Ilfracombe Limestone Series. 2. Hangman Grits, or Martinhoe beds.	Purple Sandstones and Marls. "Calcaire de Givet" (*Stringocephalus Burtini*). Schistes à *Calceola sandalina.*
Lower Devonian Series.	No Representatives.	1. Lynton Slates and Limestones.	Sandstones, Schists, and Conglomerates (Poudingue de Burnot).
			(Hiatus.)
Passage-beds and Upper Silurian Series.	Glengariff Grits and Slates. Ludlow, Wenlock, and Llandovery beds.	2. Foreland Grits. (Base invisible.)	Lower Silurian Schists &c. (Ardennes).

IX. Belgian Sections.

A recent visit to the valleys of the Meuse and Ourthe in Belgium, following on a study of numerous maps and memoirs*, has enabled me to obtain a clearer idea than I previously possessed of the Devonian series of that country with a view to comparison with that of North Devon and the south of Ireland. After observing the splendid sections along these rivers of the beds from the Carboniferous Limestone down towards the base of the Devonian series, it was impossible to come away without being impressed with the importance of the Devonian rocks amongst the formations of Northern Europe, fully justifying Sir R. Murchison, Prof. Ferd. Römer, and other geologists in giving them a position second to none amongst Continental groups†. The distinct infraposition of the Upper Devonian beds to the Carboniferous is perfectly clear and indisputable in the sections of the Meuse, north of Dinant, and in those of the Ourthe, south of Liége. The beds are different from the Carboniferous both in mineral character and order of succession; so that it is impossible to suppose they can be repetitions. At the same time the beds themselves are wonderfully bent, flexured, and folded; but there is no difficulty in determining their position and relations to each other when once the succession has been clearly made out.

That the Devonian beds of Belgium are representative of those of North Devon is abundantly clear as regards their palæontology, the main distinction in their composition being the greater predominance of limestones in the Belgian area, and of sedimentary beds in Devonshire.

It seems to me very difficult, if not impossible, to determine the representative beds in Belgium and Devonshire, except in a few cases. That the "Psammite du Condroz" is the equivalent of the "Pickwell-down sandstone" has been recognized by Prof. Dewalque, and does not admit of a doubt. In Belgium, however, it is in all probability a marine formation, Spirifers and other fossils occurring in the lower part; and it is overlain by fossiliferous shales (representing the "Lower Limestone Shale" of England), by which it is separated from the Carboniferous Limestone. The "Calcaire de Frasne," with *Spirifera disjuncta*, which underlies the "Psammite du Condroz," is an important limestone formation in the Liége district, though apparently represented only in South Devon. It is considered by Prof. de Koninck to be a subordinate member of the Upper Devonian group. The "Calcaire de Givet" is the most important limestone member of the series, and, as indicated by its fossils, is the representative of the Ilfracombe and Plymouth Limestones on the one hand, and of the Eifel Limestone on the other.

* Dumont's Carte géologique de Belgique, maps and sections of the districts of Dinant and Namur, issued by the government survey under M. le Directeur Dupont. Sections and specimens, in the Museum of Brussels, by MM. Dumont, Gosselet, Dupont, and Mourlon; together with memoirs by MM. Gosselet, De Koninck, Dewalque, &c. &c.

† I was unfortunate in not being able to examine the Lowest Devonian beds with the attention I devoted to the Upper and Middle.

The Lower Devonian beds of Belgium were deposited against a shelving shore formed of Lower Silurian rocks, the Upper Silurian beds being absent: hence these beds are often in the form of conglomerates, belonging to different geological horizons, deposited against the shores of "the Crête du Condroz"*.

X. The Boulonnais.

Of the numerous descriptions of the Palæozoic series in the Boulonnais, the latest is that by Dr. Charles Barrois†, who has given a very clear statement of the succession of the beds from the coal-measures of Locquinghen down to the lowest beds of the Devonian series as there represented. A brief *résumé* may here be useful, together with an indication of the representative beds in North Devon.

	Section of the Palæozoic Series of the Boulonnais.	*Synonyms.*
	Coal-measures of Locquinghen.	
	Hardinghen Sandstone (Millstone Grit).	
Carboniferous Limestone.	Limestone with *Productus giganteus.*	
	Napoleon marble, *P. undatus.*	
	Haut-banc Limestone, *P. cora.*	
	Dolomite, with Crinoids.	
Upper Devonian.	Fiennes Sandstone, with *Cucullæa Hardingii.*	Upper part: Marwood beds, or Coomhola Grits. Lower: Pickwell-down Sandstone.
	Red Clays and Shales.	
	Ferques Limestone, *Spirifer Verneuili.*	Calcaire de Frasne.
	Shales of Beaulieu and Dolomite of Nores.	
Middle Devonian.	Blacourt Limestone, *Orthis striatula.*	Calc. de Givet, or Ilfracombe beds.
	Conglomerates, red Shales and green Sandstones of Blacourt. Ferns and Calamites.	Hangman Grits, &c.

Lower Devonian absent. The Lower Silurian beds underlie the Middle Devonians.

XI. Representative Beds of South Wales and the Welsh Borders (Region of Siluria).

It is insisted upon by nearly all writers that on the borders of Wales, near Ludlow, there is a perfect conformity and actual passage from the uppermost Silurian into the lowermost beds of the Old Red Sandstone‡ (or "Cornstone formation"). While this is allowed to be the case in the direction of Shropshire, it is hinted by Sir R. I. Murchison § that in Brecknockshire, Caermarthenshire, and

* On this subject, see the papers by MM. Cornet et Briart, Ann. Soc. Géol. de Belgique, t. iv.

† Proc. Geol. Assoc. vol. vi.; also Sir R. Murchison, 'Siluria,' p. 411, 4th edit.; Mr. Godwin-Austen, Quart. Journ. Geol. Soc. vol. ix. p. 231, &c.

‡ De la Beche, Mem. Geol. Survey, vol. i. p. 50; Ramsay, Phys. Geol. and Geogr. of Great Britain, 5th edit. p. 104; Murchison, 'Siluria', 4th edit. p. 246.

§ *Ibid.* p. 247.

Pembrokeshire there is an unconformity between the two formations; this is the direction in which lie the tracts of the south of Ireland on the one hand, and Devonshire on the other; and owing to the overlap of the Old Red Sandstone near Caermarthen onto the Lower Silurian rocks, the passage-beds are hidden from view *; we have therefore no opportunity for comparing the Lynton and Foreland beds with their presumed representatives in time north of the Bristol Channel until we reach the district of Usk, a considerable distance therefrom. Nevertheless there seems no objection to the supposition that the purple and reddish sandstones, shales, and conglomerates of the Ridge of the Trichrag †, underlying the so-called "Old Red Sandstone" near Llandovery, are the representatives of the Foreland beds on the one hand, and of the Glengariff beds on the other.

The Pickwell-down Sandstone and the Old Red Conglomerate of the south of Ireland are, it may be assumed, represented by the "White Sandstone and Conglomerate" underlying the "Limestone Shale," this latter being the representative in a greatly reduced form of the Carboniferous Slate of the south of Ireland, and the Barnstaple, Pilton, and Marwood beds of Devonshire ‡. Between these two horizons lie the red, grey, and greenish sandstones and marls, with earthy limestones of "the Cornstone group," which must therefore represent the Middle and Lower Devonian beds deposited under conditions differing from those under which the Devonshire strata were formed. Mr. Godwin-Austen and Prof. Ramsay are of opinion that these beds are lacustrine §; I would venture to suggest, as more probable, that they were of estuarine origin, and connected with the open sea which spread over the Devonian region to the south. Mr. Salter discovered in 1862 a bed of *Serpula* (*S. advena*) in the marls of the "Cornstone series" at Caldy Island in South Pembrokshire, showing the introduction of marine conditions at least in this district. Prof. Dewalque has pointed out that similar red sandstones and marls occur amongst the Devonian rocks of Belgium, separating the Calcaire de Frasne from the Calcaire de Givet, both being highly fossiliferous marine limestones. I have myself seen these beds, which are laid open to view in several fine sections along the valley of the Ourthe, near Liége. It must be admitted, however, that although "the Corn-

* De la Beche, *ibid.* p. 60.

† Hor. Sect. Geol. Survey, sheet No. 3, by Sir H. T. De la Beche and Prof. Ramsay.

‡ In these shales, as they occur in Pembrokeshire, the late Mr. Salter recognized numerous forms characteristic of the Pilton and Marwood beds, such as *Avicula damnoniensis* (a very abundant and typical form), *Cucullæa trapezium*, *Rhynchonella laticosta*, *Bellerophon bisulcatus*, and two other species, besides other unnamed forms of *Pleurotomaria*, *Nucula*, *Sanguinolites*, *Modiola*, *Axinus*, and *Discina*. That the Limestone Shale is the equivalent of the Barnstaple, Pilton, and Marwood (or Cucullæa-) beds, seems, therefore, to be well supported by fossil evidence. (Quart. Journ. Geol. Soc. vol. xix. p. 478.)

§ Phys. Geol. Great Brit. p. 105. The absence (so far as known) of the Old Red Sandstone fishes from the marine Devonian beds is remarkable, and is explained by the authors above referred to.

stone formation" of Hereford and Monmouth appears from its position to be inevitably the equivalent of the Middle and Lower Devonian beds, the palæontological differences are remarkably contrasted. As Sir H. T. De la Beche originally, and Prof. Ramsay subsequently, have so well pointed out, the discoloration of the waters by peroxide of iron seems to have had the effect of driving mollusks and corals from the region of the Devonian rocks north of the Severn, while fishes (such as those whose remains are found in the Cornstone group) could readily swim without injury in the waters from which the peroxide of iron was thrown down, so long as they did not disturb that substance at the bottom*. Hence, while the Devonian estuary over the area lying to the north of the Severn was unfitted to be the habitat of mollusks, corals, and crinoids, these animals flourished abundantly in the more open and purer waters of the sea which ranged over Devonshire, the south of England, and eastward towards the Rhine. The beds containing *Serpula*, discovered by Mr. Salter at Caldy Island, were probably situated on the margin of the estuary on the one hand, and of the more open sea on the other. It would therefore tend to a clearer appreciation of the true relations of these strata if they were to be called by some term such as that of "lacustrine Devonian beds" rather than that of "Old Red Sandstone," *to which they have certainly no title*†.

XII. Scotland.

According to the latest researches on the subject of the Old Red Sandstone of Scotland, there are but two divisions—a "Lower," passing down conformably into the Upper Silurian shales, and an "Upper," graduating upwards into the Lower Carboniferous Sandstones, with a complete discordance between the two series‡. These relations correspond exactly to those of the Glengariff beds of the south of Ireland on the one hand, and of the Old Red Sandstone on the other.

"The Lower Old Red Sandstone" of Scotland consists of sandstones, shales, and conglomerates, with cephalaspid and pteraspid fishes and large eurypterid crustaceans. "The Upper Old Red Sandstone," consists of red and yellow sandstones with a base of conglomerate.

* *Infra cit.* p. 51.

† The thickness of the "Cornstone formation" is probably not so great as generally supposed. Some horizontal sections of the Geological Survey (*e. g.* Sheet No. 3) only show a thickness of 2500 to 3500 feet, while others (*e. g.* Sheet No. 5) show a thickness of about 6000 feet. This, however, is somewhat doubtful, as the dip of the beds is unseen for upwards of a mile; but this amount may be taken as a maximum. The generally small dip of the beds, the occurrence of outliers of Carboniferous, and inliers of Upper Silurian rocks, occasionally over the great triangular area west of the Severn, all tend to make us hesitate in accepting the statements sometimes made of the vast thickness of these beds. Quart. Journ. Geol. Soc. vol. xix. p. 476.

‡ Prof. Geikie, Quart. Journ. Geol. Soc. vol. xvi. p. 312; Trans. Roy. Soc. Edinb. vol. xxviii. p. 347.

In all physical aspects, therefore, the resemblance between these groups in Ireland and Scotland is complete*.

The great hiatus which exists in Ireland between the Old Red Conglomerate and the Glengariff beds, occurs also in Scotland between the "Upper Old Red Sandstone" and the "Lower Old Red." The sections made by the Geological Surveyors in the south of Scotland, show this very clearly. If, therefore, I am right in supposing that this hiatus is filled up by the Middle and Lower Devonians for the Irish area, it holds good equally for the Scotch; and we are thus able to intercalate a missing chapter in the interesting physical history of Scotland.

Notwithstanding the almost certain identity in time of the so-called "Lower Old Red Sandstone" of Scotland with the Glengariff beds, it is impossible to doubt that it is a formation in the main of lacustrine origin, at least over the Caithness area ("Lake Orcadie" of Geikie). The evidence in favour of this view is too palpable to leave room for doubt, notwithstanding that at times the sea-waters may have made brief incursions. Thus in the district of Tinto and Carmichael, in the south of Scotland, a fossiliferous band is seen in the channel of Carmichael Burn which has yielded fossils of a decidedly Upper Silurian character. They consist of *Orthoceras dimidiatum*, *Dithyrocaris striata*, *Graptolites* (fragment), and *Beyrichia*. This band is considered by Professor Geikie to be 5000 feet above the base of the Lower Old Red Sandstone†; and a band occurs near the base of the formation in the district of Lesmahago, containing *Beyrichia* and some obscure remains of *Pterygotus*‡. But there is no reason why lacustrine conditions may not have prevailed over the Scottish area while the sea overspread the south and west of Ireland. These lacustrine conditions may also have extended over the north of Ireland, as there is every probability that "the Fintona beds" which occupy so large a tract east of Lough Erne, and which lie unconformably on the Lower Silurian beds of Pomeroy, are representative of the "Lower Old Red" of Scotland.

If these views are correct, it follows that the term "Lower Old Red Sandstone" is synonymous with Uppermost Silurian, and that the beds of that name in Scotland are the equivalents of "the passage-beds" of the Welsh borders, "the Foreland grits" of North Devon, and the "Glengariff beds" of the south of Ireland. On the above grounds I suggest the term "Lacustrine Upper Silurian" instead of the name hitherto in use in the Scottish area.

Evidence from Fish-remains.—I must here anticipate an objection which will probably be urged on the score of the evidence from fish-

* Prof. Geikie admits the resemblance between the Lower Old Red of Scotland and the Glengariff or Dingle beds (*l. c.* foot-note, p. 347). This view is also stated by Prof. Ralph Tate in his 'Historical Geology' (Weale's series), pp. 78, 79, who also concurs with me in considering the Upper Old Red of Scotland to be the representative of the Old Red Sandstone of Ireland.

† Mem. Geol. Survey Scot., Explan. of Sheet 23, p. 14.

‡ *Ibid.* p. 13. Silurian fossils have also been found in conglomerate of Habbie's Howe, Pentland Hills, supposed to be derivative, and are described by Mr. R. Etheridge, Jun., Proc. Roy. Phys. Soc. Edin. 1874.

remains. Out of a list of between 50 and 60 species enumerated by Prof. Geikie from "the Lower Old Red Sandstone" of the north of Scotland (Lake Orcadie), not one occurs in the Upper Silurian beds, according to Sir R. Murchison*. But it should be recollected that, according to Professor Geikie's own showing, the northern basin was completely isolated from that of the borders of Wales (the Welsh lake), which, as I have hinted, was rather in all probability an estuary opening out upon the sea in the direction of the Bristol Channel, Devonshire, and the south of England, which would sufficiently account for the complete dissimilarity in the ichthyic fauna of the two regions. Comparing the list given by Sir R. Murchison with that of Mr. Etheridge, however, I find that in other districts the following seven species are common to "the Lower Old Red, and the Ludlow and Passage-beds," viz. *Auchenaspis Salteri*, Egert., *Cephalaspis Murchisoni*, Egert., *C. ornatus*, Egert., *Onchus Murchisoni*, Ag., *Pteraspis Banksii*, Huxl. & Salt., *Pt. truncatus*, Huxl. & Salt., and *Pt. Lloydii*, Ag. Several genera of crustaceans are also common to both.

From these considerations I draw the conclusion that there is really in the British Isles, as elsewhere, only one formation of "Old Red Sandstone" properly so called—namely the upper member of that name in Scotland, the yellow sandstone and conglomerate below the Carboniferous Limestone of South Wales and Hereford, the Pickwell-down sandstone of Devonshire, and the Old Red Sandstone and conglomerate of the south of Ireland. It would also appear that "the Cornstone group" are not the representatives of the "Lower Old Red" of Scotland, but of the Middle Devonian and part of the Lower Devonian beds of Devonshire and the Continent; while "the Lower Old Red" of Scotland is the lacustrine equivalent of the Uppermost Silurian beds both of Herefordshire and of the south of Ireland, namely the Glengariff or Dingle beds. These seem to me the logical conclusions to be drawn from the facts and arguments stated in this paper. The following table will present the above conclusions in a condensed form:—

* 'Siluria,' 4th edit. p. 536. Compare with Geikie's list *supra cit.* p. 452.

Table of Representative Formations.

Formations.	Ireland.	N. Devon.	S. Wales &c.	Scotland.	Belgium.
Lower Carboniferous Series.	Carbonif. Limestone. Carboniferous Slate. Coomhola Grits.	Carbonif. Limestone. Barnstaple Slate. Pilton and Marwood beds.	Carbonif. Limestone. Limestone Shale.	Carbonif. Limestone. Calciferous Sandstone Series.	Carbonif. Limestone. Shales.
Upper Devonian, or Old Red Sandstone.	Kiltorcan beds. Old Red Sandstone and Conglomerate.	Upcot Flags. Pickwell-down Sandstone.	Red and yellow Sandstone and Conglomerate.	Red Sandstone and Conglomerate.	Psammite du Condroz.
Middle Devonian. Lower Devonian.	Absent. (Great hiatus.)	Mortehoe Slates. Ilfracombe Series. Hangman Grits. Lynton beds.	Cornstone Group.	Absent. (Great hiatus.)	Schistes de Famenne, Calcaire de Frasne. Red Sandstone and Marls. Calcaire de Givet.
Passage- and Upper Silurian beds.	Glengariff beds.	Foreland beds.	Passage- and Upper Ludlow beds.	"Lower Old Red Sandstone."	Poudingue de Burnot.

Successive Physical Phases.

It would appear from the above, that at the close of the Upper-Silurian period, represented in Ireland by the Glengariff beds, in Wales by the Upper Ludlow and Passage-beds, and in Scotland by the Lower Old Red Sandstone, there was a general elevation of all the northern and western portions of the British Isles, accompanied by flexuring of the strata, and followed by extensive denudation. In the area of the south of England, however, and adjoining continental districts it was otherwise. Here there was, on the contrary, continuous depression; and the sea overspread this area, in which were deposited the Lower and Middle Devonian beds. With the Upper Devonian stage, or Old Red Sandstone proper, the submersion of the western and northern portions of the British Isles began. Lacustrine conditions were established over the south of Ireland, portions of Scotland, and the north of Ireland. In the waters of these lakes the Old Red Conglomerates and succeeding beds with *Anodonta* were laid down; after which, by a further general subsidence, at the commencement of the Carboniferous period the sea-waters flowed in, establishing themselves over all the lower regions, and prevailing generally throughout the lower and middle stages of that formation.

General Deductions.

If the above views and arguments be correct, it follows:—

1st. That there is only one formation which can properly be termed the "Old Red Sandstone." This is represented in Devonshire by the Upper Devonian Sandstone of Pickwell Down, by the Old Red Sandstone and Conglomerate (including the Kiltorcan beds) of the south of Ireland, the Upper Old Red Sandstone of Scotland, and the Psammite du Condroz of France and Belgium.

2nd. That the so-called "Lower Old Red Sandstone" of Scotland is the lacustrine representative of the Uppermost Silurian beds of the English and Welsh borders, and of the Glengariff beds of the south of Ireland, and forms the connecting link between the Silurian and Devonian formations.

3rd. That the hiatus between the "Upper" and "Lower Old Red Sandstone" of Scotland, and between the Old Red Sandstone and Glengariff beds in Ireland is filled up in Devonshire by the Middle and Lower Devonian formations.

4th. And, assuming that the Foreland grits are (in part) the equivalents of the Upper Ludlow rocks on the one hand, and of the Glengariff beds on the other, it would appear that all over the British Islands, except the south of England and the Welsh borders, land-conditions prevailed from the close of the Upper Silurian stage, throughout the Lower and Middle Devonian stages; at the close of which there was a general re-submergence, with the formation of lakes and estuaries, during the Upper Devonian or Old Red Sandstone period. These lakes and estuaries were overspread by the waters of the sea at the commencement of the Carboniferous period.

[*To face* page 274.

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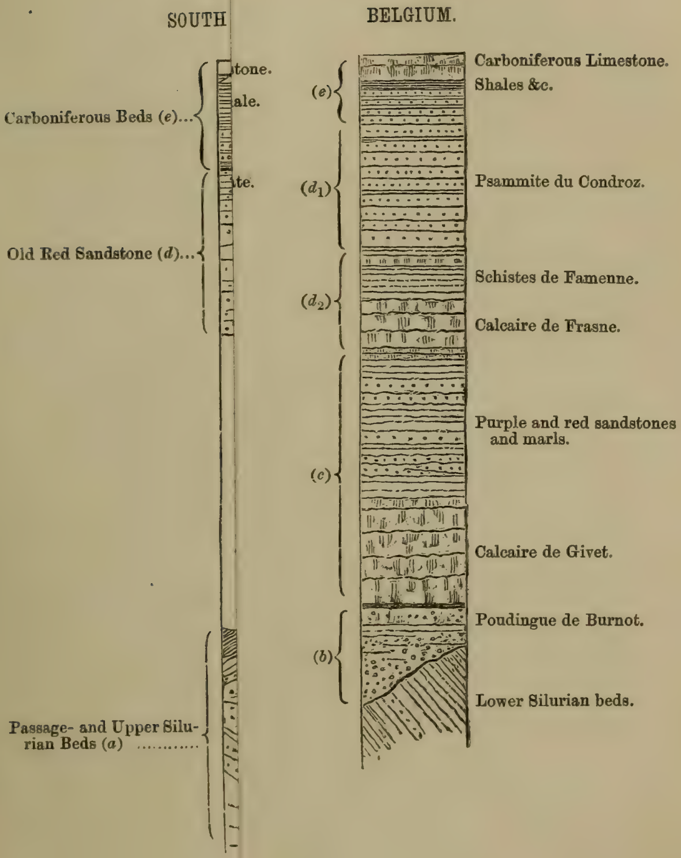

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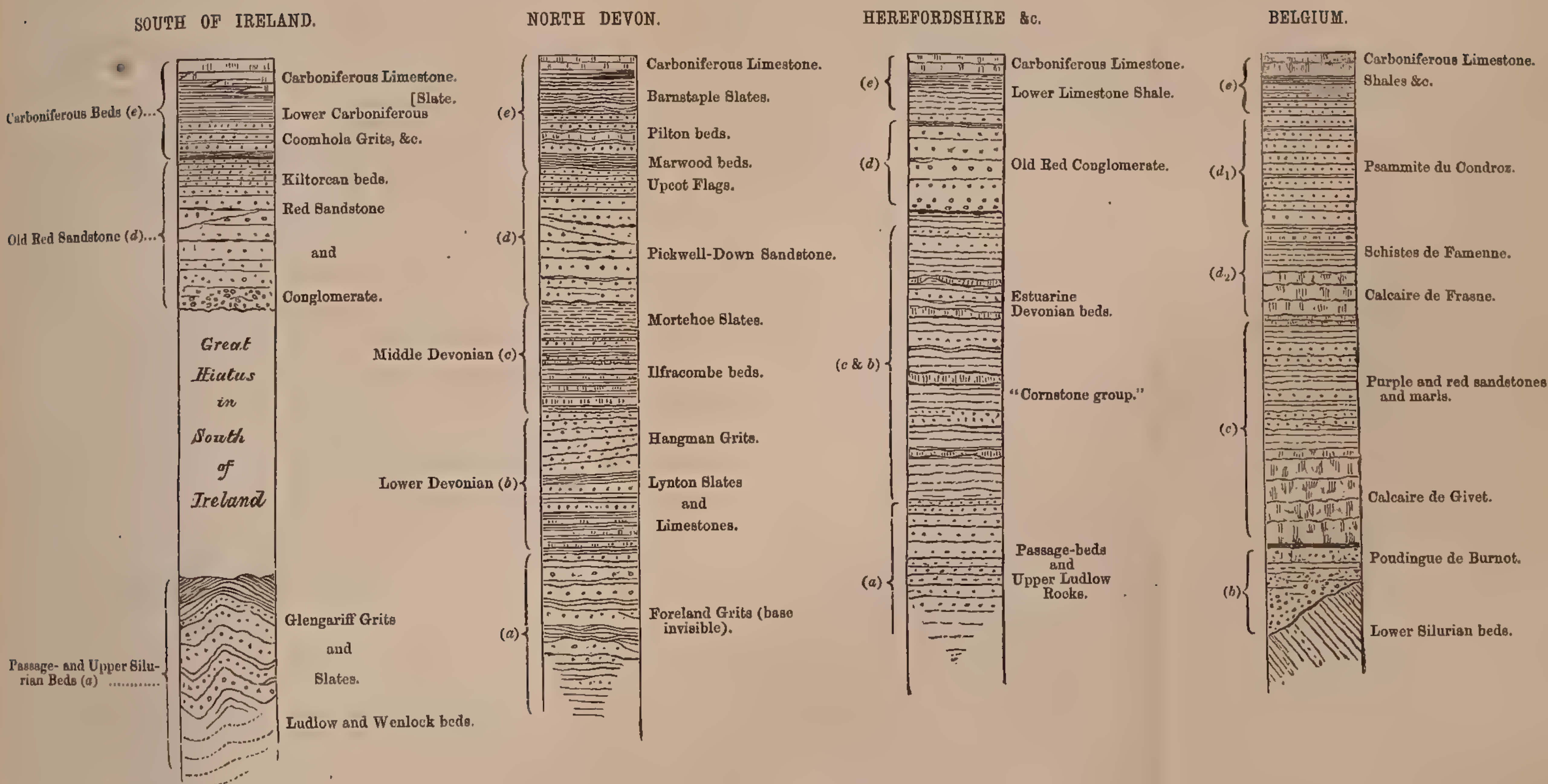
Comparative Sections of Devonian, Old Red Sandstone, and Carboniferous Formations.



Discussion.

Mr. Champernowne, speaking of North Devon, agreed that the Pilton and Marwood beds should be referred to the Carboniferous, down to the top of the Pickwell-Down Sandstones. As for the latter, he considered them, with similar beds in South Devon, Upper Devonian, and, with equal justice, true Old Red Sandstone. He thought the Morte and Dartmouth slates corresponded. The calcareous horizons of the Ilfracombe Morte series were inconstant; and in the South-Devon reefs a certain amount of irregularity might cause the Pickwell beds to rest on limestone, as at several points they appeared to do. As for the Foreland grits, he was inclined to think they might be the same as those of the Hangman, thrown down on the north by a fault. In the Quantock Hills it seemed to him that we have a great grit series, combining in itself the characters, colours, &c. of both the Hangman and Foreland series, in which case the basement series (supposed to be the Lynton grey beds) would be buried beneath them, as there is not a trace of them to be seen in these hills. In all other points he fully agreed with Prof. Hull.

Prof. Ramsay said that he was not aware that Mr. Godwin-Austen had published an opinion that the Old Red Sandstone was a freshwater deposit. There were two important points in this valuable paper:—(1) The gap in Ireland between the Upper Old Red Sandstone and the Glengariff grits. In Wales there was a perfect passage from the uppermost Silurian into the Old Red Sandstone. South of Llandovery the Upper Silurian was overlapped by sandstone and conglomerates, which at last got to overlie the Lower Silurian in Pembrokeshire; and there was very probably a break towards the middle of the Old Red Sandstone. The upper part also passed gradually into the Carboniferous series. In Scotland there are two Old Red Sandstones, viz. a lower and upper series, separated in places by well-marked unconformity. (2) The position of the Glengariff beds. He did not see why these might not be of the age of the Lower Old Red Sandstone of Scotland and South Wales, though there were lithological differences. He thought the abnormal conditions under which these appear to have been accumulated justified retaining for them the name of Old Red Sandstone.

Mr. Ussher objected to the name Upcot Flags being applied to any part of the Devonian series below the Baggy beds. He pointed out the uncertainty of correlating the Pickwell-Down grey sandstones with the "Psammites du Condroz" by lithological affinities, as the grey sandstones are merely local basement-beds of the Pickwell (Upper Devonian series), and when traced towards West Somerset, give place to purple slates, which pass down into the pale greenish Middle Devonian slates. He hinted at the bare possibility of the Foreland grits being a faulted repetition of the Hangman, as suggested by Mr. Champernowne, though the general dissimilarity between the two series, and the superposition of Lynton beds on the Foreland grits at Oare, were strongly against such a supposition.

Mr. Jukes-Browne said that, as he understood, the conglomerate at the base of the Irish Carboniferous series was confined to one horizon; but on Prof. Hull's theory every bed ought to become conglomeratic as it approached the land. Had Prof. Hull considered that point?

The President said that he wished to make a few remarks on the excellent paper which they had heard. The Foreland rocks were different from any thing to the south of them. Resting upon these grits occur the Lynton slates, with many Brachiopods; then the Hangman grits; then the Ilfracombe series, with corals in limestone bands, like those of Torquay; then the Morte slates, above which, in due succession, occur the Pickwell-Down, and the Marwood, Pilton, and Barnstaple beds. These last he paralleled with the Coomhola grits in Ireland. He felt convinced that the Foreland beds could not be the same as the Hangman grits. Prof. Hull, he thought, had shown conclusively that in Ireland there was a great hiatus between the Pickwell-Down and the Lynton beds, or the Middle and Lower Devonian. The structure of North Devon is repeated in South Devon.

The Author, in reply, expressed his gratification at the way in which his paper had been received. He could not admit that the Foreland grits and slates were possible equivalents of the Hangman grits repeated by a fault, their characters and position being different; on the other hand, their resemblance to the Glengariff beds was most striking. The point to which Mr. Jukes-Browne had called attention was difficult of explanation. He reminded Professor Ramsay that, in his previous paper, he had endeavoured to prove the Upper-Silurian age of the Glengariff beds, not only from their conformable position to the fossiliferous Upper Silurian on the coast of Dingle, but from their supposed representation by the undoubted Upper Silurian grits and slates of Muilrea in West Mayo, on the banks of Killary harbour. If this were so, he considered the name of "Lower Old Red Sandstone" for equivalent lacustrine beds in Scotland would be untenable; and he suggested instead of "Old Red Sandstone," as applied to the Herefordshire "Cornstone Group," the name of "Estuarine Devonian." He was glad to hear Mr. Champernowne's correlation of the beds of North and South Devon.

18. *On the* CAMBRIAN (*Sedgw.*) *and* SILURIAN BEDS *of the* DEE VALLEY, *as compared with those of the* LAKE DISTRICT. By J. E. MARR, B.A., F.G.S. (Read June 25, 1879.)

IN comparing the beds of the Dee valley * with those of the Lake district, we find a strong similarity in strata referred to the same age, as we might expect, considering the proximity of the two areas. The chief differences appear to be due to the two areas having been affected by intense volcanic action at somewhat different periods, the effects of which were felt throughout the ages which followed the period of outburst. This had the effect of causing a local physical break to occur earlier in the northern than in the southern district. But such local breaks as occur in volcanic districts, although more apparent than breaks more widely spread in extent, which are frequently somewhat obscure (owing probably to a uniform action of upheaval, and hence a check of denudation), cannot be of any thing like such value as the latter in assisting classification.

The end of the period of great volcanic activity in the Lake district, being soon followed by a period of depression (during the deposition of the Coniston-Limestone series), did not allow of much denudation of the volcanic materials. On the other hand, in the North Welsh area, the period of great vulcanicity was soon succeeded by a period of upheaval (viz. that at the end of the Cambrian epoch); hence the products of volcanic activity were not covered by much sediment, but suffered great denudation; and in consequence of this the Silurian beds of the Dee valley are, as a general rule, composed of coarser materials than those of the Lake district, and seem to have been, for the most part, deposited in shallower water.

It seems very probable that the Snowdonian area was occupied by dry land soon after the last volcanic outbursts there, and that it remained so during the Silurian epoch, causing some of the animals of the neighbouring coasts to migrate ever and anon from the shallower-water conditions which obtained in the Dee-valley area to the deeper waters of the Lake district, of which a few examples will be presently pointed out.

The following table gives, in one column, a list of the Cambrian and Silurian beds of the Lake district; and in a parallel column are given the corresponding beds of the Dee valley.

* I have received much valuable assistance from my friend A. S. Reid, Esq., of S. John's College, Cambridge, in examining the Dee-valley area.

Epoch.	Formations.	Lake district.	Dee valley.
SILURIAN.	Upper Ludlow.	Kirkby-Moor Flags.	Unrepresented.
	Lower Ludlow and Upper Wenlock.	Bannisdale Slates.	do.
	8. Wenlock, continued.	Coniston Grits.	do.
		iii. Upper Coldwell Beds.	Dinas-Bran Beds.
		ii. Middle Coldwell Beds. Lower Coldwell Beds.	Grits above Penyglog quarry &c.
		i. Brathay Flags.	Flags of Penyglog quarry, Maeshir, &c.
	7. Tarannon Shales.	Pale Shales.	Tarannon Shales.
	6. Graptolitic Mudstones.	Graptolitic Mudstones.	Graptolitic Mudstones.
	5. May-Hill Group.	Basement-beds of Silurian.	Corwen Grits, Cerrig-y-drudion Grits, &c.
CAMBRIAN.	4. Upper Bala.	Ashgill Shales.	Hirnant Limestone ? *O.-alternata* beds, Cerrig-y-drudion ?
	3. Middle Bala.	Coniston Limestone.	Bala Limestone and overlying shales.
	2. Middle Bala in part, Lower Bala.	Borrowdale Series.	Shales and Andesitic ashes of Berwyns.
	1. Arenig.	Skiddaw Slates.	Beds of Taihirion and Arenig.

1. *The Arenig Beds.*

The lowest beds of the Dee-valley area have yielded fossils at Taihirion, near Arenig (see Cat. Cambr. & Sil. Foss. of Woodw. Mus. p. 22 *et seq.*). It is needless to treat of them at length, as their contemporaneity with the Skiddaw Slates is generally allowed, and also their lithological resemblance to that formation, and the fact that they show signs of great volcanic activity in Wales, but not in the Lake district.

2. *The Lower Bala Beds.*

At the close of the Arenig period vulcanicity appears to have shifted its action from North Wales to the Lake area; and the Lower Bala of the Lake district consists of a series of ashes and lava-flows, well known as the Borrowdale series of Professors Harkness and Nicholson.

The Dee-valley beds of this age are made up of imperfectly cleaved shales, with a few ash beds, and some doleritic masses, which occur along lines parallel to the strike of the beds, as mapped by the Geological Survey. The ashes and doleritic rocks are seen on the slopes of the Berwyns, south of Llandrillo. About 300 yards S.E. of the farm of Blaenydre, which is about a mile south of Llandrillo, occurs an ash, which varies from a fine rock with calcite to a coarse rock containing fragments some of which are apparently andesitic. Prof. Bonney has kindly examined this and other rocks microscopically; and his descriptions are given below*.

One of the doleritic rocks is well seen on the side of Clochnant, about a mile and a half E.S.E. of Blaenydre, where it is traceable by a broken edge of outcrop†.

The occurrence of the andesitic ash is of interest, pointing, as it does, to a connexion with the Borrowdale volcanic series, as described by the Rev. J. Clifton Ward (Mem. Geol. Survey, Lake Dist. p. 13 *et seqq.*).

3. *The Middle Bala Beds.*

Although this period was one of great volcanic outbursts in the Snowdon district, it appears to have been comparatively quiescent in the Dee-valley area; consequently we here get a strong lithological resemblance to the Lake-district beds of this horizon. The Bala Limestone has been correlated with the Coniston Limestone, but would seem to have been deposited during the earlier part of the Coniston-Limestone period, as above it a series of shales occurs, whereas similar shales are intercalated with the bands of limestone in the Lake district.

At this period we get the first signs of those migrations towards the Lake-district area which occur at least twice in the later deposits. Though many of the fossils of the Bala Limestone are identical with those of the Coniston Limestone, we find that two of the commonest Trilobites of the former, *Phacops apiculatus* and *Trinucleus concentricus*, as also the genus *Echinosphærites*, which is very typical of this rock, are not found in the Coniston, but occur abundantly in the overlying Ashgill Shales‡.

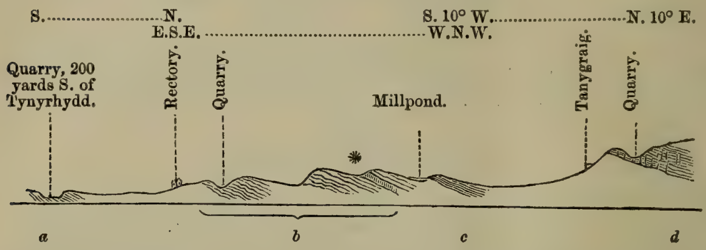
* [Rock 300 yds. S. E. of Blaenydre. This seems to be a true ash, *i. e.* pyroclastic rock; there are at least two marked varieties among the fragments:—one of scoriaceous aspect, with base rather dark from opacite, and distinct felspar crystals having glass enclosures, mostly plagioclase; the other generally with microlithic crystals, and some indications of flow-structure. It is very probable that, as you suggest, the rock is an andesitic ash. It is rather decomposed in parts, secondary products being formed, and ferrite replacing opacite.—T. G. B.]

† [Rock from side of Clochnant. A crystalline rock, consisting of well-preserved augite, much decomposed felspar, and a serpentinous mineral or minerals, with iron peroxide, probably (in part at least) ilmenite. The felspar appears to have been plagioclase; a little of a monoclinic zeolitic mineral in radiating aggregates is now present, possibly heulandite. The serpentinous mineral may replace olivine; but in some cases the form of the grains does not very well accord with this supposition. There is one crystal of a brown hornblende, a variety which I have occasionally met with in old crystalline augitic rocks. This is one of those coarse doleritic rocks common in Wales, and more likely to have been intrusive than interbedded.—T. G. B.]

‡ In a former paper (Q. J. G. S. vol. xxxiv. p. 872) I stated that *Echinosphærites Davisii*, *E. balthicus*, *E. mammosus*, *Holopella*, and *Holopea* were Coniston-Limestone fossils; the beds containing them have since proved to be in the Ashgill-Shale series.

Another remarkable instance is seen in the Brachiopod *Leptæna quinquecostata*, which is found in the limestone of Bala, but in the Lake district has not been certainly found lower than the beds intercalated with the Graptolitic mudstones, where it is abundant; it occurs there also in the middle and upper Coldwell beds.

Section in the Neighbourhood of the Rectory, Cerrigydrudion.
(Length of Section about $\frac{1}{3}$ mile.)



a. Grey Bala Shales.
b. Undulating series of calcareous grey grits, false-bedded and ripple-marked, with many clay-galls. (Near the top of these are blackish-grey cleaved bands, as at *.) The whole of *b* is probably the equivalent of the Corwen Grits, and passes up into *c*.
c. Leaden-black, cleaved, pyritous shales, with many Graptolites = Graptolitic Mudstones. *d.* Pale-green cleaved shales = Tarannon Shales.

4. *The Upper Bala Beds.*

It is somewhat difficult to know which of the Dee-valley beds should be included under this head. The Hirnant Limestone is placed here by Salter and others (see Cat. Cambr. & Sil. Foss. Woodw. Mus. p. 72); and it is characterized by *Orthis hirnantensis*, stated by Davidson (in his 'Monograph of Palæozoic Brachiopoda') to be undistinguishable from *Strophomena siluriana*, the characteristic Brachiopod of the Ashgill Shales, which are also placed on this horizon.

There is also a calcareous grit, from which I obtained *Echinosphærites Davisii*, just below the pale shales by the roadside about $\frac{1}{4}$ mile S.W. of Maeshir, which is probably to be referred to this series.

Neither of these beds shows much correspondence in lithological character with the Ashgill Shales; there is one locality, however, where the beds do bear a strong lithological resemblance to these shales, viz. the shales with *Orthis alternata*, seen by the roadside, one mile south of Cerrigydrudion. Besides abundance of *Orthis alternata*, they contain Crinoid stems, *Beyrichia*, and *Lingula*; and in them is seen an ash bed*. They occur not very far from the outcrop of

* [Rock 1 mile S. of Cerrigydrudion. A rock probably of pyroclastic origin, but so much altered by pressure and subsequent chemical change that it is difficult to form an opinion. Certainly many of the fragments are of igneous origin. The felspar is much decomposed, and various secondary products are abundant. All that it would be safe to say is that the fragments do not belong to the more acid group of lavas, probably they are andesitic; but seeing that the rock has been much altered, they might be yet more basic. (If the rock is rich in carbonate, the latter is probably the case.)—T. G. B.]

the Silurian beds, and nevertheless are troughed in by large faults on all sides; hence they must be very high up in the Bala series; and they are quite different lithologically from any other Bala beds in the neighbourhood. *Orthis hirnantensis* is recorded by Salter from Cerrigydrudion; and it most probably comes from these beds.

It may be remarked that ashy beds occur in the Ashgill Shales of the Lake district, at Spengill.

5. *The May-Hill Group.*

In a paper by Prof. Hughes (Q. J. G. S. vol. xxxiii. p. 207) a series of gritty beds is described under the name of the Corwen Grits, and these beds are taken to represent the base of the Silurian (Sedgw.), and correlated with the Austwick Conglomerates &c. of the Lake district. At the rectory, Cerrigydrudion (see Section, p. 280), an undulating series of calcareous grey grits, false-bedded and ripple-marked, with numerous clay-galls, is seen resting unconformably on the Bala beds; and these grits are intermediate in lithological character between the Corwen Grits and the Plasuchaf beds near Cyrnybrain, described also by Prof. Hughes in the above-cited paper. They were apparently unfossiliferous where examined, though *Pentamerus oblongus*, quoted from Cerrigydrudion, was probably found in these beds.

The beds at the rectory form a strong feature; and the base is seen to rest in an undulating manner upon the underlying even-bedded Bala beds. These gritty beds, and the immediately overlying ones, which I shall presently describe, are included by the Geological Surveyor in the Bala Series.

In lithological character, the gritty series of Cerrigydrudion resembles the calcareous and gritty bands at the base of the Silurian of the Lake district proper, *e.g.* at Skelgill and Pullbeck near Ambleside, and Appletreeworth Beck near Coniston. Towards the top it contains one or two finer blackish grey bands, which show cleavage.

6. *The Graptolitic Mudstones.*

In the Cambridge Museum, "*Graptolites* sp. with very narrow cells" is placed among the middle Bala fossils and recorded (Cat. Cambr. & Sil. Foss. Woodw. Mus. p. 39) as from Bala. The matrix in which the fossil occurs is excessively like that of the Graptolitic Mudstones of the Lake district; and the species itself is *Monograptus argenteus*, Nich., which characterizes a single zone of the Graptolitic Mudstones in the neighbourhood of Windermere &c. I was therefore led to infer the occurrence in this district of the equivalents of the Graptolitic Mudstones, and, although unable to detect them in the country immediately around Bala, obtained the following section near Cerrigydrudion (see fig. p. 280).

In this section the gritty beds on the horizon of the Corwen Grits lie, as already described, unconformably upon the Bala beds of the valley, and they pass up into a series of well-cleaved blackish pyritous mudstones, exactly like those seen in Church Beck, near

Coniston. From these mudstones the following species were obtained:—

Ovarian capsules of Graptolites?	*Monograptus tenuis.*
Monograptus convolutus, var. *a*, *communis.*	—— *gregarius.*
—— *Sedgwickii?*	—— *colonus.*
	Climacograptus teretiusculus?

They are seen near a millpond about 250 yards W.N.W. of the rectory, and curve round, so as to become exposed again in a quarry close to the mill, which is further down the stream than the pond and about the same distance from the rectory. Here about 15 feet of them are seen, but there is no indication of the top beds being visible. In each place they contain thin bands of subordinate grit.

They are succeeded in ascending order by the Tarannon Shales of the Survey, which are exposed in natural sections and in a quarry near the farm of Tanygraig, just above the mill-pond.

There are therefore three reasons for referring these beds to the Graptolitic Mudstones:—First, lithological character, which we have seen already to be of considerable importance in comparing the two areas. Secondly, stratigraphical position; for these beds occur between the Tarannon Shales, which have been correlated by Mr. Aveline with the Pale Shales of the Lake district (Geol. Mag. Decade ii. vol. iii. p. 282) and the gritty beds which Prof. Hughes correlates with the Austwick Conglomerates. Thirdly, palæontological affinity: of the Graptolites found, all save one are characteristic Graptolitic-mudstone fossils in the Lake district; this one, *Monograptus colonus*, is characteristic of much higher beds, the upper Coldwell beds, and supplies another instance of migration from Wales to the Lake district. With regard to the palæontological evidence, we can state at once, from the presence of *Monograpti*, that the beds are Silurian; for there is no well-authenticated instance of a typical *Monograptus* occurring in the Cambrian series; also we may infer, from negative evidence, that these beds are not the equivalents of the Brathay Flags, for in that case *Monograptus priodon* and *M. vomerinus* would certainly be among the first fossils found; but the only other Graptolitiferous beds in England about this horizon are the Graptolitic Mudstones themselves; consequently there can be no doubt that these beds must be referred to that series.

Similar black beds are seen above the Corwen Grits of Nant Caweddu, near Corwen.

7. *The Tarannon Shales.*

These beds have, as before remarked, been identified by Mr. Aveline with the Pale Shales of the Lake district, which they exactly resemble, except that, like the Graptolitic Mudstones of the Dee-valley area, they are more cleaved than is usually the case with the corresponding beds of the Lake district.

8. *The Denbighshire Grits and Flags.*

There are three distinct subdivisions of this series in the Dee-valley area. (i.) The lowest of these consists of the banded slates of Penyglog quarry &c. These have been identified with the Brathay Flags of the Lake district, which are quite similar; they contain also the same fossils. From the beds of this series at Penyglog I obtained *Acroculia haliotis*, which has not yet been found below the upper Coldwell beds of the Lake district.

The same beds occur in the course of a stream about $\frac{1}{3}$ mile south of Maeshir, where they are faulted against the Tarannon Shales: they here have somewhat the same lithological character as the Graptolitic Mudstones, but contain numerous well-preserved specimens of Graptolites, among which were *Monograptus priodon* and *M. vomerinus* in great abundance; *Retiolites Geinitzianus* and *Orthoceras* also occurred.

These beds in the Dee valley are succeeded by (ii.) Gritty beds, *e. g.* those above Penyglog quarry, which are probably on the horizon of the lower, and perhaps also of the middle Coldwell beds, than which, however, they are much coarser, indicating a shallower sea at this period than was the case in the Lake district.

(iii.) The highest Silurian beds of the Dee valley are well exposed on the hill near Llangollen upon which Dinas-Bran Castle stands. They have been correlated with the Llansannan Shales by the Geological Survey. In lithological character they resemble the upper Coldwell beds of the Lakes, having the same peculiar character of breaking into prismatic blocks; they also form the marked screes so typical of the upper Coldwell beds. This identification is rendered more certain by the correlation of these beds by the Geological Survey (Mem. Geol. Surv. vol. iii.) with the Llansannan Shales, which have a well-marked upper-Coldwell fauna. In the case of these shales, however, as in the case of the Dinas-Bran beds, many of the fossils which occur are not found in the Lake district lower than the Kirkby-Moor Flags and Bannisdale Slates.

The following list of fossils from Dinas Bran is compiled from the Woodwardian Museum and my own collection:—

Spongarium Edwardsii, *Murch.*
Serpulites dispar, *Salt.*
Favosites fibrosus.
Actinocrinus pulcher.
Ceratiocaris.
Rhynchonella navicula, *Sow.*
—— nucula, *Sow.*
Ambonychia acuticostata, *M'Coy.*
Cucullella coarctata, *Phill.*
Ctenodonta.
Theca Forbesii, *Sharpe.*
Holopella gracilior, *M'Coy.*
Orthoceras tenuicinctum, *Portl.*
—— laqueatum, *Hall.*
Cycloceras ibex, *Sow.*

Of these fossils, *Spongarium* and *Rhynchonella* occur in the Bannisdale Slates and Kirkby-Moor Flags of the Lakes; but most of the other fossils are found in the upper Coldwell beds. The identification of these beds with the upper Coldwell beds depends on the following facts:—(i.) the lithological and petrological character; (ii.) the stratigraphical position; (iii.) the correlation by the Geological Survey with the Llansannan Shales, which have a decided upper-Coldwell fauna; (iv.) the character of the fauna of the beds themselves, which resembles the upper-Coldwell fauna, mixed with fossils occurring at a higher horizon in the Lake district, and indicating a migration.

These beds, although so like the upper Coldwell beds, were deposited in a shallower sea, as indicated by the micaceous character of the beds, the numerous ripple-marks, and tracks and borings of Annelids.

The beds above the upper Coldwell beds of the Lake district do not seem to be represented in the Dee valley; but since the highest beds of the latter area show extremely shallow-water conditions, it is possible that this may be not altogether due to denudation, but partly to deposition having ceased in the area for some period.

19. *On the* SCHISTOSE VOLCANIC ROCKS *occurring on the west of* DARTMOOR, *with some* NOTES *on the* STRUCTURE *of the* BRENT TOR VOLCANO. By FRANK RUTLEY, Esq., F.G.S., H.M. Geological Survey. (Read January 21, 1880.)

(Communicated by permission of the Director-General of the Geological Survey.)

AFTER examination of the schistose beds of rock on the western margin of the Dartmoor granite, I experienced great difficulty in coming to any satisfactory conclusion concerning the origin and real nature of many of them. These rocks had already been described by Sir Henry De la Beche, in his Report on the Geology of Cornwall, Devon, and W. Somerset, as schistose ashes; and his well-known keenness in detecting lithological peculiarities naturally induced me to accept his opinion, especially as it seemed in some instances to be a very correct one. There was, however, one point which caused me considerable perplexity. I could not reconcile the very frequent occurrence of a densely amygdaloidal structure with the persistently schistose character of these rocks. If the amygdaloidal condition implied a once vesicular structure, and if the rocks should on this account be regarded as lavas, how then was the schistose character to be accounted for? I was not then acquainted with any instance of schistose lava. On the other hand I could not understand why, if these rocks were ashes, they should be amygdaloidal. In my memoir* on the eruptive rocks of Brent Tor and its neighbourhood I endeavoured to account for the schistose structure in lavas, and for the amygdaloidal condition in ashes, and in many places expressed my doubt about the true character of these rocks. Ever since those lines were written I have been anxious to ventilate this matter, and, if possible, to arrive at a more satisfactory solution of the difficulty. It is to Mr. John Arthur Phillips that I owe the suggestions which have at last helped to settle the question. On expressing my doubts to Mr. Phillips, and after showing him the specimens which I had collected, he at once stated his belief that these schists were precisely similar to some which he had met with in Cornwall, and which he had examined and described as lavas. On re-examining my microscopic sections I was still unable to satisfy myself that he was right in his conclusion; but I thought my sections were perhaps not sufficiently thin, and therefore made an examination of some new and better ones which were prepared by Mr. Cuttell. At once I realized the truth of Mr. Phillips's views. The majority of the types which I had selected were evidently lavas of a more or less vesicular character, while the others were ashes, fine tuffs (Schalsteins), or sedimentary schists.

In some of the latter amygdaloidal structure is present; and it is just possible that even these may represent greatly altered lavas. One section cut from a specimen collected by Sir Henry De la Beche, and labelled "Vesicular ash," is an unquestionable lava. Never-

* Memoirs of the Geological Survey, 1878.

theless Sir Henry was certainly right in his views concerning some of these rocks, which present the appearance of fine sediments in which fragments of scoriaceous and other volcanic rocks are imbedded; and it was doubtless from a consideration of these particular rocks that he was led to generalize, and to regard nearly the whole of these schists as ashes. The schistose structure has doubtlsss resulted from the pressure of the superincumbent strata which once covered this area, a circumstance which I pointed out in my official memoir. It may, however, also be partly due, in some cases, to the profuse development of vesicles compressed and elongated in the direction of flow. That these beds are alternations of lava-flows, tuffs, and tufaceous sediments I have no longer any doubt.

I have learnt the importance of examining only the thinnest possible preparations of rocks of this class, and the importance of expressing a guarded opinion when microscopic rock-sections fail to reveal distinct characters; I would also here thank Mr. H. W. Bristow for affording me facilities for the re-examination of some of the specimens collected for the Survey.

The structure of the schistose lavas is in some cases quite clearly shown when very thin sections are examined under the microscope; but as they have all undergone considerable alteration, it is not easy to speak with certainty about their original mineral constitution. There are numerous little felspar crystals to be seen in them; and they sometimes lie with their longest axes in definite directions more or less approximating to the direction in which the vesicles are elongated, and which also coincides with the planes of bedding and schistosity. A considerable quantity of viridite is present in most of these rocks; in some cases it seems to be allied to green earth, and in others to a scaly chlorite-like mineral. I cannot help thinking that these rocks may owe their present fissile character to the elongated vesicles which occur so plentifully in them.

The felspars are usually very minute, and are often represented by pseudomorphs only. These lavas were most likely similar to some of the highly vesicular basalt lavas erupted at the present day.

There is an important consideration suggested by the comparatively uniform character of these rocks in the Tavistock, the Saltash, and the Cornish districts; and it seems to me possible that it may be one which should to some extent influence the position of the boundary line between the Devonian and the Culm series on the west of Dartmoor. In dealing with this question I am fully aware of the value of palæontological evidence, and how such evidence must of necessity dominate over any argument based merely upon lithological characters. Unfortunately, in parts of this country, and especially in the critical part now under discussion, fossils are, I believe, few and far between; and I therefore venture to offer the following remarks in the hope that they may incite palæontologists to focus their attention for a short time on a small tract of country which seems at present to be doubtful ground. I refer to the tract lying between Tavistock on the south and Lidford on the north. Here the lavas and their associated ashes and tufaceous sediments crop out in strips or belts which, for the most part, trend in an approximately east and west direction, while on the west of Brent Tor they are shown on the Survey map to sweep round in a rude semicircle. These strips, which I shall call the volcanic series, dip at very low angles or are in some places approximately horizontal; and I believe that in many cases they are repetitions of the same bed or set of beds—a view ably advocated by Dr. Harvey B. Holl in his paper on the older rocks of South Devon and East Cornwall*.

If this be really so, how can we have one part of a bed situated in the Devonian, and another part of the same bed cropping out in Carboniferous rocks? yet, as the Survey map now stands, this appears to be the case. Justice must, however, be done to the statements published by Sir Henry De la Beche, since in his Report already cited, at page 116, he says "The boundary is certainly unsatisfactory between the Tamar and the granite near Tavistock." Again an important statement occurs at pages 119, 120:—"In the country near Dunterton, Milton Abbot, Lamerton, Brentor, Mary Tavy, Peter Tavy, and Tavistock, the mass of schistose ash accompanied by greenstone and other trappean rocks is very considerable. In this district also the geological date of the solid trappean rocks may be questioned; but that of the schistose ash is clearly the same with the various grits and shales, it being merely doubtful to which of the two great systems of rocks some of the beds may be referred near Milton Abbot, Lamerton, and Távistock. Some perfectly similar rocks occur in both; and the boundary between them, as has been above noticed is not clearly defined."

Further on, on the same page, Sir Henry says, "There can be little doubt that the principal band [*i. e.* the Milton-Abbot and Dunterton band of the volcanic series] is included in the upper series, as it can be seen to rest upon very characteristic rocks of that series. With a more southern band of a similar ash commencing with Endsleigh, and which is well exhibited in some quarries on the line near Combe, continuing thence by Lamerton and Kilworthy to Sowtentown, there is not the same certainty." With the most profound respect for Sir Henry De la Beche's opinions, I cannot refrain from pointing out the probability of beds near the junction of two perfectly conformable formations exhibiting alternations in lithological character which render it impossible in a very limited area such as this to speak with any certainty as to the precise formation; and since Sir Henry adduces no palæontological evidence in support of his opinion, I think it becomes an open question whether weight should or should not be attached to his statement. The point I wish to establish is this, that we have at Saltash, as recorded by Mr. J. A. Phillips, some schistose lavas in the Devonian series identical with some of those which occur in the Devonian series further north, in the neighbourhood of Tavistock—and that similar rocks occur still further north, round about Brent Tor, and trending westward as though they belonged to the Launceston and St.-Clether series of eruptive rocks which are included in the Devonian area. If, then, the

* Quart. Journ. Geol. Soc. 1868, vol. xxiv. p. 407.

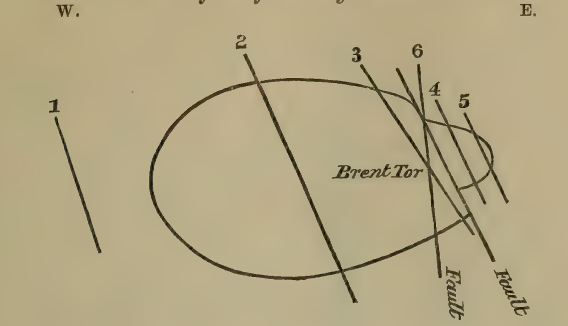
schistose rocks of the volcanic series in the vicinity of Brent Tor are merely repetitions of those about Tavistock, ought they not all to be regarded as of late Devonian age? and may they not be correlated with those in the Saltash district, which are unquestionably Devonian? That this southern Devonian series of rocks has been elevated by the underlying granitic masses, such as that at Hingston Down, seems to be clearly indicated by the well-marked east-and-west trend of the long elvan dykes which cross the country; and if this be the case, the discrepancy in the dip of the rocks about Brent Tor and those about Saltash is sufficiently accounted for, while at the same time we can readily realize the denudation of the once intervening and more elevated portions of these schistose rocks over a tolerably wide area. Mr. J. A. Phillips adduces good reason for thinking that some of these lavas and tuffs were restricted to small dimensions; and he is doubtless right to a certain extent. I cannot, however, help thinking that in other cases they covered a very considerable area; and I believe that some of the Saltash and Tavistock schistose lavas may possibly have represented a large and once continous flow. I do not, however, wish to urge this opinion very strongly, as I have not visited the Saltash district, but have merely examined one or two specimens collected by Mr. Bauerman. I would also disclaim any desire to remove my neighbours' landmarks or tamper with existing geological boundary lines, when ignorant of all the arguments which may be brought to bear upon such a question, since this paper has been written merely to record a little additional information concerning the nature of the schistose volcanic beds of the Brent-Tor district and to direct the attention of geologists to a very small area in which they may possibly rectify a "scientific frontier" by carrying the Devonian rocks a mile or two further north.

Before any more really careful work can be done to elucidate the structure of this district and the stratigraphical relations of the eruptive rocks which occur so plentifully in it, it will be necessary to survey it upon a map of larger scale, a proceeding which would prove beneficial to miners as well as to geologists.

The rocks treated of in this paper are, for the most part, situated, as already mentioned, in the immediate vicinity of Brent Tor; and it seems more than probable that they emanated from it, as suggested by Sir Henry De la Beche. Having now discussed the characters of these schistose beds of lavas, tuffs, and tufaceous sediments, it may not be out of place to attempt, by a series of sections, based in part upon the Survey Map, to restore the old volcano itself.

Treating the subject broadly, we may say that Brent Tor stands on an irregular oval basin (fig. 1) occupied by its lavas, tuffs, and ashes, which are interstratified with sediments hitherto considered to be of Carboniferous age, but which, as I have suggested, may possibly turn out to be Devonian. The basin is cracked across in a nearly north-west and south-east direction by a fault, the downthrow being to the west. Brent Tor is situated on the downcast side of the fault; and it is to this fact that its preservation is due. The basin-like area is mainly represented by Heathfield. Further to the west the beds

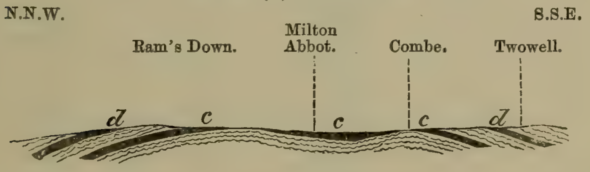
Fig. 1.—*Plan of the Brent-Tor Basin, showing the Faults and the lines of the following Sections.*



are thrown into long anticlinal and synclinal folds. On the west a small and nearly triangular area includes all that remains of the Brent-Tor volcanic series in this direction. To the south it is possible, as suggested in this paper, that the schistose beds about Saltash, ten or twelve miles distant, may belong to this volcanic series.

The first section which I have taken to illustrate the relations of the beds is one running N.N.W. across Ram's Down (fig. 2). It

Fig. 2.—*Section* (1) *across Ram's Down.*



lies on the west of our typical basin. Here two beds of the volcanic series are seen, the older marked with the letter *c*, the younger with *d*. As they undulate, and their crests have been denuded, there are three separate exposures of the bed *c*, flanked on either side by the bed *d*. In speaking of these exposures as beds, it should be understood that they commonly consist of a *series of beds* (lavas, tuffs, &c.).

The next section (fig. 3) runs in a S.S.E. direction, from Littonary Down, across Heathfield, to Tavistock. From Meather to Churlhanger we see a synclinal disposition of the beds, which dip northwards towards Lower Chillaton and Quether, while on the south the bed *c* is repeated by several undulations, and is then succeeded south of Tavistock by what I believe to be two older lava-flows, lettered respectively *a* and *b*. These four series of beds *a*, *b*, *c*, and *d* represent, so far as I can ascertain, the whole of the Brent-Tor volcanic series subjacent to the stack of lavas and agglomerates which constitute the tor itself.

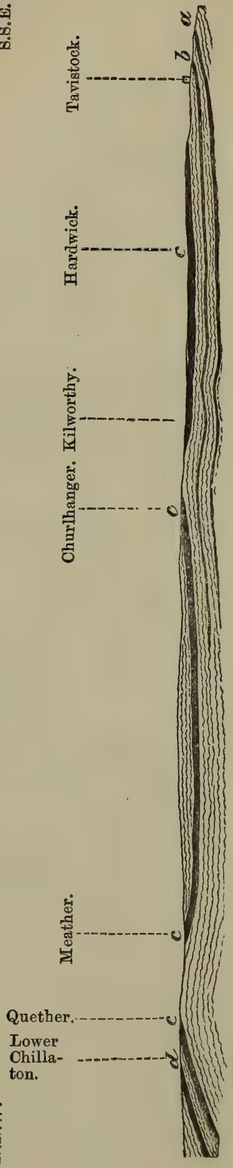


Fig. 3.—*Section (2) from Littonary Down to Tavistock.*

Fig. 4.—*Section (3) touching the Southern Edge of Brent Tor (south side of Fault).*

In fig. 4 we have a N.W. and S.E. section, passing from Littonary Down on the north to Mary Tavy and Ridge on the south, and just cutting the southern boundary of Brent Tor. We have here the broadest part of the Heathfield basin. The turn-over of the volcanic beds *c* at Monkstone appears to be a probable though by no means a certain rendering.

Sections 4 and 5 (figs. 5 & 6) are taken in a N.W. and S.E. direc-

Fig. 5.—*Section* (4) *East of Brent Tor.*

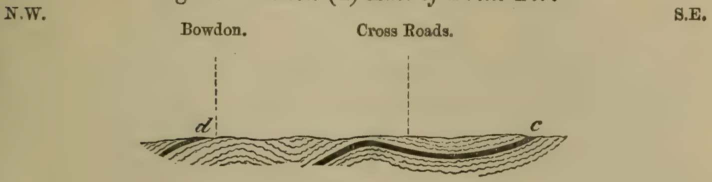
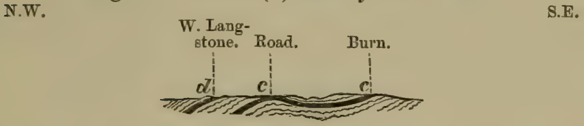


Fig. 6.—*Section* (5) *East of Brent Tor.*



tion through the little triangular area on the east of the Brent-Tor fault. Here the volcanic beds *c* and *d* only are represented, and the flexure and northward dip of *c* must again be taken as an expedient but not very trustworthy version of what may possibly occur along this line. In drawing these sections I have fully accepted the data furnished by the Survey Map; but, from a short examination of the ground, I am inclined to think that in some few instances the boundary lines are not absolutely correct.

Fig. 7 is a section taken a little west of north through Brent Tor, ranging from Bowdon to Tavistock. Here the whole of the Brent-Tor volcanic series of lavas, agglomerates, tuffs, ashes, and the associated sediments is shown. The fault is also indicated; and the feeder of the volcano is represented as coincident with the fault. The denuded portions of the cone are also suggested.

Fig. 8 is a chimæra which *may* embody a certain amount of truth. Here the downcast is shifted up to its normal position: we see the old furnace in full blast, and its long undisturbed lava-flows *a*, *b*, *c*, and *d*, with tuffs, ashes, and sediments interbedded.

The little black hummock represents what remains of the original cone.

In fig. 9 I have roughly indicated the possible relation which may exist between the volcanic series of Brent Tor and that of Saltash, the granite of Hingston Down lying about halfway between the two series and pushing up the intervening beds in an anticlinal fold. The dotted lines are mere suggestions of the vast thickness of strata carried from off this area by denudation. I have also indi-

Fig. 7.—*Section (6) nearly N. and S. through Brent Tor (along Western Fault).*

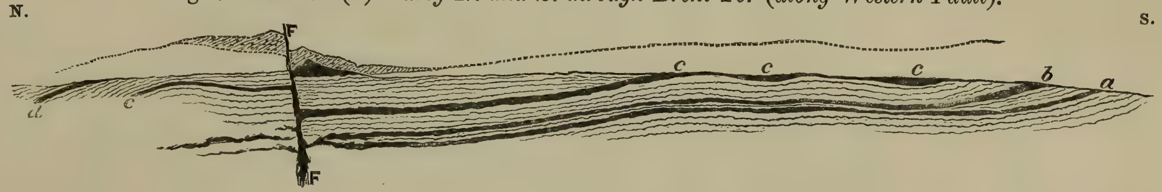
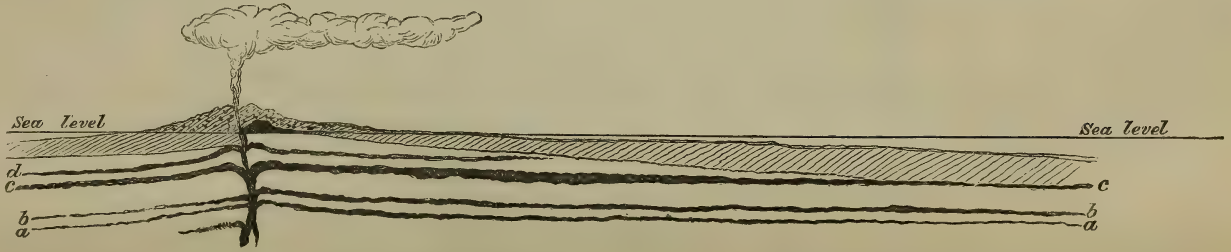


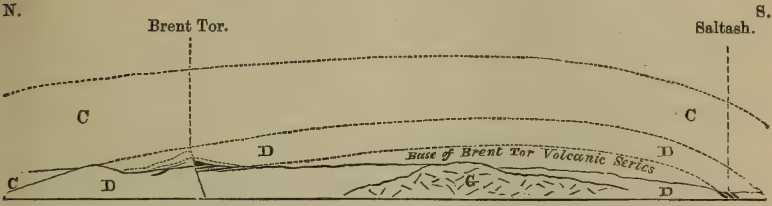
Fig. 8.—*Brent Tor restored.* The black portion represents all that remains of the cone.



FF. Fault. Missing portion of the cone. Rock removed by denudation.

cated the possible alteration of the boundary lines between the Culm series and the Devonian rocks.

Fig. 9.—*Diagram to illustrate the possible Relation of the Brent-Tor Volcanic Series with that of Saltash.*

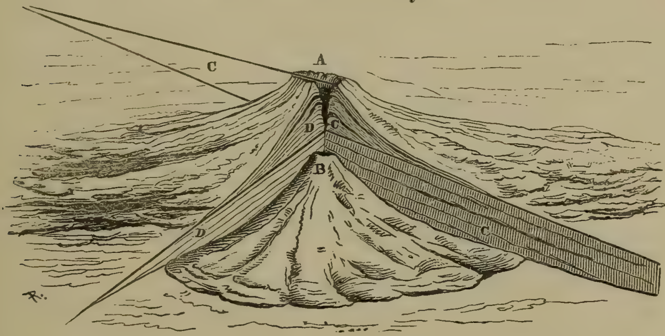


(The dotted lines indicate rocks now removed by denudation.)

C. Carboniferous. D. Devonian. G. Granite of Hingston Down.

Fig. 10 is an attempt to show in a diagrammatic manner the downthrow of the existing portion of the old Brent Tor volcano between the two faults, which were first described by Dr. Holl. That these

Fig. 10. *Diagram to illustrate the Manner in which part of the Brent Tor Volcano has been faulted.*



A. Chief part of the cone.
B. Part of the cone faulted down.
C. Fault running N.W. & S.E.
D. Fault running nearly N. & S.

faults originated as radiately disposed fissures emanating from the axis of the cone seems highly probable, since similarly situated fissures are common in many modern volcanos. From this diagram it will be seen that by far the greater portion of the cone has been long since removed by denudation. A considerable amount of the downcast part must also have disappeared, leaving only the mere mole-hill from which I have endeavoured to reconstruct the mountain which geologists will always associate with the name of Sir Henry De la Beche.

The flue of the volcano was probably situated somewhere along the line of junction of the two faults. The superior portion was most likely denuded together with the upcast part of the cone; while the remainder may either be faulted beneath the present surface of the ground, or may possibly be represented by a basalt which occurs at the foot of Brent Tor on the northern side.

In dealing with the preceding questions I have merely expressed opinions which are based upon a fair but not very extensive series of facts, all, unfortunately, which we have at our disposal at present. More must be learnt concerning the lie of the beds before we can speak positively upon many of the questions raised in this paper. There yet remains much for geologists to work out in the country between the Tavy and the Tamar. In speaking of the possible relation between the volcanic series of Brent Tor and that of Saltash I am fully aware of the danger of basing arguments merely upon lithological characters; and I should be loth to assert, because two series of rocks were identical in mineral constitution, in structure, and in mode of occurrence, that they therefore belonged to the same geological horizon. The broader questions discussed in this paper are neither to be solved by a few weeks of desultory stone-breaking, nor by a life-time of speculation based upon imperfect data.

More facts must be accumulated before we can thoroughly understand the structure of the Brent-Tor district.

Discussion.

The President, in returning thanks to the author, stated that he had met with amygdaloidal cavities, due to the giving off of gases, in some of the older slaty ashes.

Mr. Thorpe called attention to a specimen of lapilli from Brent Tor, found in the joints of a limestone at Newton Abbot. He thought these proved that the S.W. wind blew in Devonian times.

Prof. Ramsay wished to ask the President where the slates with amygdaloidal cavities were.

The President said in Cumberland.

Mr. Etheridge thought that in the area treated by the author the junction between Devonian and Carboniferous (as marked in the Survey Map) was brought too far south, and that these rocks will prove most valuable as indicating the boundary-line here, as in Cornwall. It was unfortunate that no fossils had as yet been discovered in the area under notice.

Prof. Hughes agreed in removing the boundary-line further north. He was perplexed at hearing Mr. Thorpe speak of open fissures existing in Devonian times in Devonian rocks, and still to be seen. He pointed out that the material was arranged vertically, as in a calcareous deposit, not horizontally as if dropped into an open fissure; and he asked whether Mr. Thorpe had tested the material with acid.

Mr. Thorpe gave some explanation of the mode of occurrence.

Prof. Bonney agreed that many of the rocks were lavas, but doubted if crushing accounted for their foliation. A foliated structure might come from resistance of hard amygdaloids, cleavage, alteration of a fluidal structure, and deposit on a fissile face. He thought, perhaps, the last the most probable explanation in this case, as the cavities did not appear materially crushed.

Prof. Maskelyne said that a spongy lava saturated with water which had no exit would not necessarily crush.

Mr. Bauerman agreed that these rocks were small lava-flows interstratified with shales. He compared these Brent-Tor rocks with the Nassau Schalstein.

Mr. J. A. Phillips said that analyses of this rock showed that the lime in the carbonate of lime had been derived from felspars. He exhibited a specimen of Nassau Schalstein. Cornish Schalstein contained ·64 per cent. of phosphoric acid; that from Nassau ·57 per cent. Staffelite occurred below the Nassau Schalstein.

The Author thought that Mr. Thorpe's specimen was not a volcanic, but a calcareous tufa. He thought the schistose structure due to the elongated vesicles, so that the rock split along the planes of least resistance. Prof. Maskelyne's suggestion was well worthy of consideration.

20. *On* Mammalian Remains *and* Tree-trunks *in* Quaternary Sands *at* Reading. By Edward B. Poulton, Esq., M.A., F.G.S., of Jesus College, Oxford, Burdett-Coutts Scholar of the University, formerly Demonstrator in the Biological Department of the University Museum. (Read January 21, 1880.)

The pit furnishing some interesting sections to be described in the following paper is situated on the Redlands estate, at Reading, a little east of the new Grammar School, and about a mile south-east of the market-place. The pit is about halfway up the south slope of the conjoined Thames and Kennet valleys, and is 36 feet above the river-level. It has been worked for gravel and sand for some years, and recently for clay; and the gravel-bed, from 10 to 15 feet in thickness, has been cleared out over an area 276 feet in length from north to south, and of about the same average length from east to west, where, however, the boundaries are irregular and, to the east, partly effaced. The beds exposed in the north face are far more perfect and instructive than elsewhere. This face, about 20–25 feet in average height, and, where completely exposed, 65 feet in length, is drawn to a scale of $\frac{1}{15}$ in. to the foot in fig. 1.

A. About 12 feet thick, represents the gravels and recent strata overlying certain reconstructed beds of sand and clay.
  (1) 1 foot 6 inches thick, is the superficial alluvium containing elements derived from the waste of the gravel below.
  (2) 2 feet 6 inches thick, is transitional between the alluvium and the underlying gravel. It consists of rounded and subangular flints scattered thinly through a base of yellow clayey soil.
  (3) 8 feet thick, is the gravel containing bones of land-mammalia. A rough stratification is apparent; and there are some intercalated beds of sand. A considerable thickness of this, with long, ramified, lateral prolongations, is seen about the centre of the exposed gravel. There is a large amount of ferruginous cement, and everywhere a deep staining of iron oxide.

No river-shells were detected, although I made a careful search for them, assisted by much earnest inspection of kind friends. I found a flake about halfway up the gravel-bed; but this may have fallen from the higher alluvium, although this derivation appears doubtful, because the vertical face of the cliff affords such slight opportunity for lodgment*. The elements of the gravel are derived from the following sources, in the order of their relative preponderance:—

(*a*) *Chalk.* Subangular flints, derived from the waste of the chalk, are the chief constituents of this gravel. Some few are quite

* Since writing the above another, more perfect flake was found by me (April 8th) on a gravel-path near the pit. The gravel certainly came from the pit; and it is highly probable that the flake was carried with it. Neither of the specimens can be referred with certainty to either the Neolithic or the Palæolithic period.

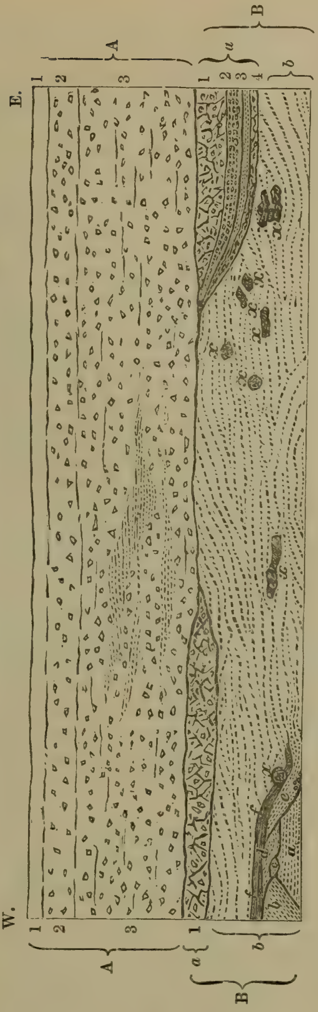


Fig. 1.—*Section in North Face of Pit near Reading.* (Scale $\frac{1}{15}$ inch to 1 foot.)

unworn and have sharp edges; they must have been transported by floating ice-blocks and so have escaped rolling. Flint casts of *Ananchytes* and *Galerites* are tolerably common; and one good example of a Ventriculite was found. Of the more perishable constituents of the Chalk, a few rounded nodules of hard chalk and a worn fragment of *Inoceramus*-shell were found.

(β) *Tertiaries.* There is a considerable proportion of rounded flints derived from the destruction of these beds. A fair specimen of *Ostrea bellovacina* from the same source was also found.

(γ) *High-level gravels.* There occurs, thinly scattered through all parts of the gravel, a small proportion of rounded quartzite masses derived from the waste of the high-level gravels that once formed an uninterrupted layer across the then unexcavated valley.

(δ) *Occasional elements transported from a distance.* Worn fragments of *Ostrea* (chiefly *O. dilatata*) occur; and one worn *Nerinæa* was found from the Oolites near Oxford. A small piece of blue, fissile limestone, when broken, showed the characteristic structure of Forest Marble. This must have been carried 41 miles if derived from the nearest source, Islip on the river Ray, and if it followed the general direction of the river-valley without taking the sinuous curves of a river.

This description holds good for all the gravels of the four faces of the pit. The west and north are still well seen; the east and south are now entirely covered up.

B. The reconstructed beds, about 9 feet thick. These consist of Tertiary elements (Woolwich and Reading beds, and to some extent the basement beds of the London Clay) altered and rearranged by fluviatile agency and interpenetrated by river-gravels and with bones of land Mammalia and tree-trunks. At either end, east and west, of this north face, reconstructed clays intervene between a thick bed of sand and the superimposed gravels. Centrally, however, the clays are absent, and the gravel and sand come into contact. Here, however, in the lower part of the gravel slight indications of the clay may often be found, but no regular layer. To the east end of the section many layers of intermixed clay, sand, and gravel intervene between the gravels and sand, forming the group of beds marked *a* (1, 2, 3, 4) in fig. 1, while the west gravels and sand are separated by only one subdivision, the equivalent of the eastern uppermost layer, and therefore marked *a* (1). The characters of the reconstructed clays (beds *a*) are as follows:—

(1) 2 feet thick, east and west side. Large fragments of mottled clays from the upper part of the Woolwich and Reading beds. These are entirely unstratified, and there is an irregular intermixture of rounded flints (from waste of Tertiaries) and subangular ones (from chalk). Above, this layer passes into the gravel, with no definite line of demarcation, by the gradual cessation of the clay masses. Additional proof of the Post-glacial and fluviatile origin of this layer is found in a few rounded quartzite masses, from the high-level gravels, which were taken from its lowest part. In one part of this bed on the west side the clay masses more resemble those of (2) layer in being finely broken and slightly laminate.

(2) 1 foot 6 inches, east side. Finely broken mottled clays, slightly stratified and containing fragments of bivalve shells. The stratification and shell-fragments are entirely quaternarily imposed characters, both completely absent in the Tertiary clay from which the bed was derived. The shells are so fragmentary that identification is impossible; their general appearance, however, is such as to render probable their origin from the basement beds of the London Clay, which crops out higher up the slope. The last 4 inches of this layer graduate into a yellow sand overlying the white sand (3). Scattered flint pebbles occur thinly throughout the layer.

(3) 6 inches thick, east side. Fine white sand.

(4) 6 inches thick, east side. Coarse fragments of mottled clay, roughly stratified, and with white sand between the layers. Gravel is present, especially in the lowest part, overlying the thick bed of sand (*b*).

These four beds, above described, thicken out eastward; while to the west the lower ones rise to the surface of the sand (*b*), and they all die out between it and the gravel. Each of the four thins away at this point; and there is a tendency towards their coalescence or interlamination, especially in (2) and (3). These beds indicate powerful and rapid currents transporting the materials from the Tertiary clays higher up the slope, and cutting away the sands previously deposited by gentler aqueous agency. The lowest bed (4) on the east side, and (1) on the west, overlie the sands quite unconformably, the laminæ of the latter being cut through very sharply. The currents must have been very powerful to remove *masses* of the extremely tough and stiff mottled clays. They cannot have been long continued, or the clay masses would not have been angular but would have been further disintegrated and redeposited elsewhere, losing the readily apparent characters by which their origin is at once seen. The broken lumps are of exactly the same colour and structure as the undisturbed beds higher up the slope. The force of the aqueous agency is further seen in the steep incline on which the beds are deposited; deposition in comparatively still water would have produced horizontality in the strata.

(*b*) This stratum consists of a bed of sand 9 feet thick where it extends upwards to the gravels with no intervening clays. Its base is not seen in this north face; for water is reached at the level drawn on the section. It is derived mainly from the destruction of the "Buff Sands" of the Woolwich and Reading series. The sands are generally white, but often yellow or orange, from ferruginous staining, especially near the included tree-trunks, one of which often discolors the sand for a few feet round it. The sand-grains immediately surrounding the trunks are often bound together into an extremely hard conglomerate by a ferruginous cement; and the whole is generally firmly adherent to the trunk itself. Small pebbles occasionally occur in the sands. The whole bed gives one the impression that it was subject to long-continued but gentle fluviatile action, as compared with the clays above. The condition of the bones found in this bed is in favour of this view; for they are very waterworn and yet unbroken, while those of the gravel above are often broken sharply but their surfaces are far more perfect. Curiously the shifting currents and eddies of fluviatile deposition have produced a result strikingly like the original "Buff Sands" from which these beds were derived. The general irregular arrangement of the bedding only is given over the main part of the section (although the imbedded plant-remains (x) exposed in the face are accurately placed); but to the west and below, a series of beds showing the oblique laminations very distinctly are drawn carefully to scale.

The beds are lettered in the order of their deposition.

(*a*). The first deposited, and forming the axis of the group, is horizontal, and was therefore probably thrown down in comparatively still water. The laminæ are of coarse yellow and white sand, becoming deeply orange from ferruginous colouring in some parts. Small pebbles are common; and there are thin laminated clay-seams in the lower part and to the west—additional proofs of the gentle aqueous agency.

(*b*). Then followed swifter currents from the east and directed downwards, cutting away the west part of (*a*), so that its laminæ terminate abruptly in a slope of 45°. Against this, as the current became gentler, the bed (*b*) was deposited of fine white sand below, coarse above.

(*c*) and (*d*). Then currents from the west cut away (*b*) and (*a*) nearly horizontally, and (*c*) and (*d*) were deposited on them. These are of very fine white sand. There is an unconformability between (*c*) and (*d*) to the west, caused by some change in the current after (*c*) was thrown down. East, they form one bed.

(*e*). After this, more rapid currents from the west removed the east part of (*d*) and (*a*); and on the steep slope thus formed the fine white sand forming the bed (*e*) was deposited. In its lower part a few angular lumps of bluish clay occur, evidences of the rapidity of the currents, probably derived from the destruction of the "Leaf-beds."

(*f*). Finally gentler currents from the west planed off the tops of (*b*) (*d*) and (*e*), and on them deposited the laminated sandy clay (*f*). This contains traces of vegetable matter in which no structure can be made out; and there is much oxide of iron in the layers and concentrically laminated nodules. I found in this clay a few rounded flints still retaining their green coating and thus proving that the materials had partially been derived from the lowest bed of the Woolwich and Reading series, the layer of green-coated flints just above the Chalk. This rendered probable the view that the laminated clay itself was derived from the destruction of the Leaf-beds, which occur just above the green-coated flints in the undisturbed Eocene strata. The clay much resembles that of the Leaf-beds in its blue colour. The sandy intermixture is, of course, a newly imposed character given during the redeposition among these beds of sand. The clay is horizontal west, but east it descends a steepish slope; and towards the bottom of this a large tree-trunk (*x*) is seen, partially enclosed in the clay, and exposed in transverse section. The relation of the tree-trunk to the slope gives the impression that this water-logged mass, rolling down under the slow action of the current from the west, has been the cause of the cutting away of (*e*) to a slope, while further west the beds (*b*) and (*d*) are planed off horizontally. Further probability is given to this view by the fact that east of the trunk the clay-band again becomes horizontal before it dies away, in a few feet.

Imbedded Remains. These have nearly all been found in the excavations at this north face; and hence the whole organic remains of the pit are best described here, since nothing different has been found in other parts. Omitting the indication of man by the flake probably belonging to the gravel (A), the remains of the pit are of three kinds—Mammalian bones and teeth, tree-trunks, and derived shells.

Mammalian Remains. These have been partly found in the gravel (A) and partly in the sand B (*b*). Many were found in the laminated coarse sand marked (*a*) to the west and below, thus occurring quite 8 feet below the under surface of the gravel (A). The bones and teeth were distributed in various directions to different collectors; and those from the gravel and sand have been indiscriminately mixed. The difference, however, is generally easily recognizable, remains rom the gravel being broken rather than waterworn, usually stained yellow with iron oxide, and sometimes still showing the smaller constituents of the gravel adherent to their surface, while those from the sand are more waterworn and whiter. In some cases I have direct testimony as to the beds in which they were found. The identification of the species, or even in some cases naming the bones, was extremely difficult; but putting together the characters of the bones and teeth, the following list was made out, and may be taken as trustworthy:—

ELEPHAS PRIMIGENIUS.

(1) Two perfect molar teeth of young individual between sand (*b*) and gravel (A), also fragments of teeth from gravel.

(2) Portion of left scapula with part of glenoid cavity. Gravel (A).
(3) Proximal epiphysis, with articular surface intact, of one of the first phalanges of right hind foot. From sand (*b*).
(4) Many fragments from gravel are evidently *Elephas* from their size, but they are unidentifiable.

Bos primigenius.

(1) Right scaphoid, in good condition. Sand.
(2) Right distal articular extremity of right metacarpal or metatarsal. Sand.
(3) One of the last dorsal vertebræ of a young individual, the posterior epiphysis being lost. (Sand?) This broken specimen can only be considered approximately identified.

Equus fossilis.

(1) Two molar teeth and some fragments. One certainly came from between the sand and gravel; the rest are undecided.
(2) One of the last two lumbar vertebræ, much waterworn. (Sand.)
(3) First phalanx (?). Gravel.
(4) Proximal half of left metacarpal, very small specimen. Between sand and gravel.

Rhinoceros tichorhinus (?).

A portion of the articular surface of an astragalus shows undoubted perissodactyle characters, and is too large and shallow for *Equus*. It may be *Rhinoceros*. (Gravel.)

For the loan of the specimens from which the above list has been made, or for information on this subject, I have to thank Mr. F. W. Andrewes, of Christ Church, Oxford; Mr. C. H. Armstrong, of Friar's Street, Reading; and Mr. Walter Palmer, of The Acacias, Reading. In some of the most difficult identifications I have to thank Prof. Flower, and Mr. Jackson and Mr. Robertson of the University Museum, for much kind help, and above all Prof. Rolleston for the use of the splendid collection of comparative osteology and for the teaching that I have had in that subject in his department during many years.

Tree-trunks. These occurred in the sand-bed B (*b*) exclusively, and chiefly in its lower part. Those at present exposed in the face are seen in fig. 1 (x, x), generally in transverse section. The trunks are a foot or more in diameter, and some of them several feet in length. They are always horizontal, and had probably been carried down by the stream from some distant locality, as I could never detect any traces of lateral branches or, indeed, any indications of bark. The structure is very much obscured by the iron oxide with which they are impregnated. All attempts to render the tissue transparent failed; and hence some siliceous replacement is probable together with the iron. Sometimes the wood is friable or even pulpy, sometimes extremely hard and interpenetrated by quartz-grains in a ferruginous matrix. At first the attempt was made to grind sections of this indurated part; but much labour, with a very doubtful prospect of success, was saved by examining the softer tissue as an opaque object by reflected light. Some less-altered fibres from the centre of a mass of wood whose periphery was quite obscured by iron oxide were chosen for examination. This central tissue split up readily into its component fibres on being merely touched with the needle; and these, when examined with a No. 4 Hartnack, in the manner mentioned above, showed all the characteristic appearances of the tissue of *Pinus*. Fragments of the medullary rays were seen quite distinctly crossing the pitted vessels at right angles. I have to thank Prof. Lawson for his kind help in working at, and making out the structure of, the wood.

Derived Remains. Between the sand and gravel, where these come into contact and the clays are absent, a curious admixture of derived and proper remains occurs. As shown in the above list, teeth of horse and *Elephas* and a bone of horse were found here; but with them were the following derived remains:—

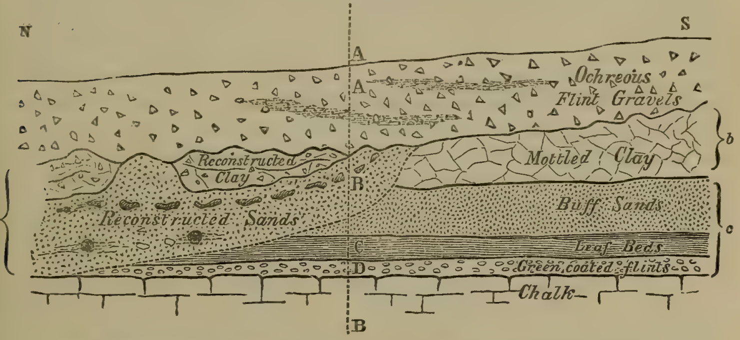
(1) *Ostrea dilatata*, from the Oolites at Oxford, abundant but worn.
(2) Worn fragments of *Inoceramus* from the Chalk; and a worn Belemnite, probably from the same source.
(3) *Ostrea bellovacina* from the Woolwich and Reading Series. Abundant and perfect.
(4) Shell-masses from the basement beds of the London Clay, with many of the shells still very perfect and recognizable (*Natica*, *Pectunculus*, &c.).

This heterogeneous collection, found at one horizon only in the deposits, serves to indicate the diverse and widely separated strata from which the bed has been formed.

I was anxious to procure the entire section of this interesting and very perfect face, and thus to gain a complete knowledge of all the beds over the Chalk at this point. However, on digging at the base of the sands, water came in at all points along the face. This is held up by some clay-bands above the Chalk; and their top was reached by the spade. The clay may be the reconstructed Leaf-beds, or perhaps these beds continued under the reconstructed sands in an unaltered condition. The sand was so full of water at this level (about 1 foot beneath base of cliff) that we could not complete the section. Hence in fig. 1 the face terminates below in a water-line. To reach the Chalk we chose a spot 78 feet south of, and at right angles to, the east end of the north face, just under the imperfect and irregular east face of the pit. Here we suffered no inconvenience from the water, and the Chalk was reached in about 5 feet. The pit was dug by Mr. F. W. Andrewes (my friend and former pupil) and myself; and I must express my hearty thanks to Mr. Andrewes for his help in the really considerable labour of cutting through the stiff clay, as well as for many other services in connexion with this work. The owner of the pit, Mr. Winter, kindly gave us permission to do as we liked, and afforded us every assistance in his power. The pit sunk was 5 feet long by 2 feet wide; and the Chalk was seen at a point 5 feet 4 inches below the greatest depth reached by the men, and as nearly as possible 30 feet from the surface. Careful measurements of the beds dug through in the pit, and those above, gave the following results. The dotted vertical line (AB) in fig. 2 shows the section here described:—

			ft.	in.
Quaternary.	A.	*Alluvium and concealed gravel*	6	8
		Gravel exposed	10	0
	B.	*Reconstructed clays*	absent.	
		Reconstructed sands	8	3
Tertiary (Lower Eocene).	C.	1. *Laminated clays* (blue, yellow and grey, with plant-remains)	1	1
		2. *Sand and thin clay*		2
		3. *Laminated clays* (bluer than 1, but with plant-remains as there)		7
		4. *Yellow sand* (with an indurated ferruginous layer below, 1–2 in.)		3
		5. *Homogeneous blue clay* (non-laminate, with concretions of iron-pyrites and a little vegetable matter)	2	2
	D.	*Green-coated pebbles,* and sand (no fossils)		$9\frac{1}{3}$
Secondary.		*Chalk.*		
		Total	29	$11\frac{1}{3}$

Fig. 2.—*Probable Section of Junction between Tertiary Beds and Quaternary reconstructed Beds.*



a. Reconstructed beds. *b.* Woolwich and Reading beds. *c.* Unaltered Tertiary.

The group of beds A and B correspond in this east face to the gravels and recent strata, together with the reconstructed quaternary series of fig. 1 (A and B). Beneath this the beds numbered 1 to 5 (C) were met with. At the point where these were first reached all evidences of reconstruction ceased; there was no intermixture with river-gravels, no imbedded Post-tertiary remains, no disturbance. The laminated clays 1 and 3 obviously represent the "Leaf-beds" discovered by Prof. Prestwich in the cutting of the G. W. R. line to Newbury and Basingstoke. There are none of the delicate impressions, however, shown in the latter beds in that locality or at Katesgrove. The position of the beds C, just over the green-coated pebbles, D, is also indicative of their correspondence with the Leaf-beds.

The whole series 1–5 probably corresponds to the Leaf-beds, with a little local variation. Beneath the bed D, and covering the Chalk, was a flat flint so traversed by vertical fissures that it was easily removed in cubical blocks. It extended over the entire bottom of the pit, and was therefore, as far as we saw it, 5 feet × 2 feet in area, and about 6 inches thick. At the sides it was continuous under the green-coated pebbles; and thus we could not find its true size. But while the undisturbed Tertiary beds thus underlie the sands and clays exposed in the east face, the latter are reconstructed quaternary beds, although their lowest part, just above the Leaf-beds may be undisturbed and Tertiary, as shown in fig. 2, at the line A to B. In nearly the whole height of this eastern exposure of sand (about 8 to 10 feet), and along its whole length (151 feet), irregular bands of clay-fragments occur, some still angular and retaining all the appearance they presented when the river-currents detached them from the unaltered Tertiary beds higher up the slope and transported them to this spot. Above the sand in the east face, as in the north, the reconstructed mottled clays intervene in patches between the sand and gravel. These clays are largely intersected by bands of gravel, and contain scattered pebbles. There is none of the lamination observed in the north face. Tracing these reconstructed beds of the east face southward, towards the series from which they were derived, they disappear beneath a vast pile of rubbish; and no indication of the transition is afforded. Nevertheless our pit at the base of this east cliff proved that the lower beds of the Tertiary series are continued unaltered under these derived strata; and therefore the transitional line was then reached, as shown in fig. 2. The west face, shorter but well exposed (83 feet 6 inches long), is also reconstructed as far as it can be seen; and its south end affords no hint of the transition.

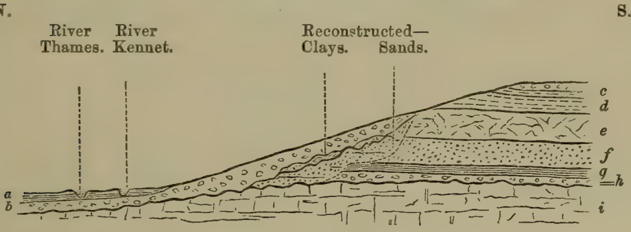
In the south-west corner of the pit, the sands have been exposed far south of the extreme southward extension of the west face of sand (for the gravel is first worked independently, and cleared out over a much greater area than the sand); and here too the beds are reconstructed. Therefore the transitional line cannot be looked for anywhere along the westward, north, and south limits of the pit.

On the other hand, further east, at the base of the former south face (now a slope of turf), the men worked a bed of homogeneous clay for some little time for brick-making; and in the sands below they found no tree-trunks or bones, and there was no evidence of disturbance. The unfossiliferous character of the clay and the oblique lamination of the sands were distinct and characteristic. This south point is 276 feet from the north face. In this distance, therefore, to the south, are the unaltered mottled clays and buff sands of the Woolwich and Reading series, while to the north are reconstructed beds of the elements of these strata intermixed with the remains of a more recent period.

Somewhere south of the present exposure of the east face is the line of junction, which may have been in the form of a low cliff or slope, of which the base was prolonged horizontally under the reconstructed bed (as seen in our pit), gently rising to the south as it approached the cliff. Fig. 2 is a section of the probable transitional line with the beds north and south of it. Such a line would be reached if the east face were exposed up to the south face. The line of junction is dotted in; for its exact direction can, of course, only be surmised. The irregularity in the junction between the unaltered and reconstructed beds, as shown by the latter extending further south at the west side of the pit, is only to be expected when it is remembered that the transitional line represents the sinuous margin of a river, and any little bay indenting the bank would carry the reconstruction into the concavity.

The relation of all these beds exposed in the pit to the whole south slope of the river-valley is well seen by ascending the incline to the limits of the Redlands estate (south). The arrangement is shown in a diagram in fig. 3; and the outcrop of the beds there

Fig. 3.—*Diagrammatic Section of South Bank of River-valley.*
(Slope greatly exaggerated, rise 79 feet in about 1 mile.)



a. Alluvial plain.
b. River-gravel.
c. High-level gravel.
d. Basement beds of London-clay.
e. Mottled clays.
f. Buff sands.
g. Leaf-beds.
h. Green flints.
(*e*–*h*: Woolwich and Reading Series.)
i. Chalk.

drawn can be verified quite satisfactorily. The gravel-bed (A in fig. 1) is seen to belong to the general system of the river-gravels.

South of the pit, ascending the slope, these gravels thin off and leave the mottled clay exposed at the surface; higher up these beds are covered by the basement beds of the London Clay, which were well exposed in digging the foundation of a house near the top of the slope. The basement beds are again capped, at the summit (79 feet above the river), by the entirely unstratified, unfossiliferous, high-level gravels, consisting of a large proportion of rounded quartzite masses and subangular flints.

Thus the south slope of the river-valley at the Redlands estate, affords a very perfect example of a typical valley-slope, and in addition presents the more exceptional appearances of the reconstruction of the Tertiary beds by fluviatile agency, in such a manner that the easily removable elements of the latter remain, though altered in structure and intermixed with the organic and inorganic remains of very different ages and widely diverse conditions. And the sections in this pit add another to the scattered evidences that occur at intervals along the valley of the Thames, proving the existence in some Postglacial time of a larger river occupying its valley and flowing at a level from 20 to 30 feet higher than the present; and in some parts of the pit the beds are so perfect as to afford evidence of the direction even of the minor currents of the river, while the organic remains give us valuable proof as to the fauna and flora that lived on its banks. When my attention was first directed to this pit, I perceived to some extent the interesting nature of the reconstruction, and sent a short account of it to Prof. Prestwich; and he very kindly came down and visited the pit, and pointed out that the reconstruction was even more extensive than I had imagined. I followed out his kind suggestion and made drawings of the best sections, and took careful notes of all parts of the pit; and from these and the specimens I have been able to collect, this paper has been written.

Discussion.

Prof. Prestwich remarked on the interest attaching to the finding of mammalian remains not associated with coarse gravel, but in finely stratified fluviatile beds, which do not otherwise occur between Oxford and Reading in the Thames valley. The finding of contemporaneous tree-trunks is exceptional.

Mr. Whitaker said that great masses of reconstructed Tertiaries beneath the gravels had not been found at other points in the Thames valley. He suggested that the reconstruction might be due to landslips and the action of springs.

Prof. T. McK. Hughes instanced a similar case of the reconstruction of Tertiary beds at the Upnor-Castle section.

The Author said certain proofs of fluviatile action in the reconstructed beds were found in the rolled tree-trunks, the waterworn bones, and the fine lamination of the sands and clays. In some instances the direction of the minor currents could be traced by the finely-bedded sands.

21. The Gold-leads *of* Nova Scotia. By Henry S. Poole, Esq., M.A., F.G.S., Government Inspector of Mines. (Read March 12, 1879.)

[Abridged.]

The character of the auriferous rocks of Nova Scotia was a subject of some discussion a few years ago*, when it was suggested that the gold obtained was from "quartz beds of contemporaneous age with the quartzite and the slate with which they are interstratified."

Dr. T. Sterry Hunt, reporting on this province the year before the subject was brought to the attention of this Society, wrote :— "So far as my present observation goes, I think that to describe the gold-lodes otherwise than as interstratified beds would be to give a false notion of their geognostic relations. The laminated structure of many of the lodes, and the intercalation between their layers of thin continuous films or layers of argillite, can hardly be explained in any other way than by supposing these lodes to have been formed by successive deposition at what was, at the time, the surface of the earth."

This description well expresses the appearance of our gold-districts ; but the theory that the "leads," as the lodes are locally called, are contemporary beds with the slates and quartzite has not since been generally accepted ; nor has it gained ground with the further knowledge derived from working, nor been adopted by any of the miners, among whom are men experienced in other gold-producing countries.

My position having enabled me to visit frequently the several districts and see the leads in their varying stages of exploitation, I have kept in mind the theory in question, and especially examined the relation of the leads to the containing rocks. Some of my observations I have expressed in the following notes.

Surface-geology of the Gold-fields.

The general features of the districts, and the position of the leads in relation to the country and rocks, may be thus briefly sketched. Along the whole Atlantic seaboard of Nova Scotia, from Seaterie to Cape Sable, Palæozoic rocks extend. The lines of stratification have an almost universally east-and-west course, and, generally speaking, are parallel with the coast-line and with the axes of upheaval, not only of the hill-ranges, but likewise of the anticlinal folds that bring the gold-leads to the surface. The leads also conform, with almost unvarying persistency, with the strike of the slates and quartzite-beds, following even the plications of the strata with remarkable regularity, thus giving rise to the idea that they might be contemporaneous beds and not intrusive veins.

* Quart. Journ. Geol. Soc. vol. xxvi. p. 477.

While quartz veins are not confined to the districts where gold is found in paying quantities, those that have been discovered to be auriferous are generally about the axes of anticlinal folds, and present an appearance which may be compared to a series of diversely shaded sheets of paper sharply bent together, tilted at one end, and cut horizontally. The lines of various shade which the sheets would then show approximately represent the position of the leads and the interbedding slates and quartzites. And, further, as that side would be the more highly inclined on which the lateral pressure found the least resistance, so do the strata incline at these anticlinals. In the districts of Sherbrooke and Uniacke, for instance, the strata are vertical on the south and incline to the north at an angle of 45°. In other districts, as Waverley, Renfrew, and Moose River the vertical and inclined dips are reversed. At Sherbrooke the leads on both sides of the anticlinal are auriferous, and are only the width of the main street apart; while at Uniacke the north dip is two miles away from the working-belt. On the top of Laidlaw's Hill, in the district of Waverley, the lead lies so flat that it is worked "longwall." In it the gold is chiefly found where it is crumpled together by the folding of the strata and forms what are called "barrels." These "barrels" or "rolls" have been followed down on both the north and south dips. On the crest they run in the direction of the axis of the anticlinal; and on either side they trend to the north and south, representing, as it were, the resultant of the forces encountered in the upheaval. In the overlying stratum the position of the plication in the quartz is marked merely by a moderate undulation. The quartz having yielded in the greatest degree to the lateral pressure would indicate that, at the time of the upheaval, it was in a more plastic condition than the containing rocks, and the more when it is observed that the rolls contain angular fragments of slate, and send offshoots and tongues of quartz up into the superjacent stratum.

The auriferous rocks are supposed to be contemporaneous with those of the Cambrian; but the horizon of the belts has yet to be determined. It has been suggested by those who consider the leads to be bedded deposits, that only the lowest rocks of the series contain the gold-leads, which the anticlinal folds have brought to the surface. But the lithological characters of the several districts point to the existence rather of three groups in which auriferous leads exist:—the lowest, composed of beds of slate and grits crumpled and contorted and cleaving transversely to the laminæ (in these no paying lead has been found); the middle, of compact beds in which quartzite predominates and the cleavage-planes generally conform to the lines of deposition (strata of this group in the neighbourhood of anticlinals are intercalated with numerous quartz-leads, some of which only are auriferous to an appreciable extent). The upper group, in the extreme western section of the province, consists of olive-green fissile slates associated with beds of micaceous sandstone and at least one plumbagineous bed. Some of the strata are highly chloritic; in the true gold-districts chlorite is a rare mineral.

Mr. Selwyn, Director of the Canadian Geological Survey, states that some of these sandstones contain pebbles of a grey quartzite, and that he is inclined to believe that these rocks will be found to occupy the position of some division of the Quebec group. Of the relative age of the gold-bearing veins that are associated with the rocks of this section there can be no doubt; for when they are exposed by the tide at Gegoggan and Cranberry Head, they are seen to angle across the beds, to swell out into masses 6 and 8 feet wide, to pinch within a distance of a few feet into less than as many inches, and again expand and contract. Such veins have been found to contain a little gold; and one at the Cream-pot, Cranberry Head, while not so irregular as some at Gegoggan, yielded as much as one ounce of gold to the ton of quartz.

Mining Experience.

Mining-operations have not been confined to the bedded leads; for rich streaks of quartz have been worked in cross leads and in the so-called angling leads. The angling leads are true veins, generally very small; they have the general east-and-west course, but break across the strata at slight angles. In depth they gradually steal across a bed of slate, but, on meeting quartzite, break short across to the next stratum of slate, and so on downwards. In nearly all cases the angling leads have been found to contain more gold when they passed through a quartzite bed.

The true cross leads as yet proved are barren, and of later age than the interstratified leads; but besides them there are bands of quartz connecting two parallel leads, and there are offshoots which are often called cross leads. They in some cases appear to affect the productiveness of the regular leads. For instance, at the junction of a cross lead with the belt lead at Montagu some spots gave as high as 40 ounces of gold to the ton. And at Cariboo (area 629, block II.) an offshoot appeared to govern the direction of the richest portions of the lead; the stope which cut it, 40 feet wide and 20 fathoms deep, yielded 12,000 ounces, chiefly from parcels taken on the line of the offshoot. Whether the yield from the bedded leads is in reality affected by the position of cross leads and offshoots may be doubted; for there are many more offshoots, and perhaps cross leads, than there are gold streaks. But it appears to be a rule that the dips of the gold streak and offshoot are in the same direction. One thing is certain, that the contents of the leads are irregularly distributed, and that their metallic minerals are not uniformly mixed, but are aggregated about certain spots and in certain directions. The paying beds are generally small, of a few inches only; many will not average 4 inches in width; and one of 8 inches is regarded as of good size, though some thicker have been worked. Regularly interstratified stringers, threads, and offshoots of quartz may be seen extending from them into the walls. A stringer from the Wellington lead proved rich when it passed through the slate footwall, but barren in the succeeding bed of quartzite. The Murray lead in the same district of Sherbrooke showed at one spot a number of stringers entering the footwall. The quartz from them collected together yielded 7 ounces of gold.

Sooner or later in the working of the regular "bedded" leads irregularities characteristic of veins are met with. Late operations at Waverley on the Union lead, one of those referred to in proof of the bedded origin of the leads, have shown the quartz to cease, while the line of fracture is seen to continue its regular course. In one stope a large "horse" of quartzite cut off the quartz; in another the quartz formed a compact "roll" 8 feet wide, from which ramified into the footwall a number of suckers.

In the course of working the parallel leads a layer of quartz is sometimes noticed to "take in" in the adjoining bed of slate. One such layer was opened at a depth of 600 feet in the hanging wall of the Wellington lead.

In both slate and quartzite walls of leads, crevices containing little or no quartz occasionally contain gold. One flat-lying crack in the quartzite wall of a strong barren lead at Uniacke gave 3 ounces of gold, where there was only a little iron-rust and no quartz visible. Gold is also found in the slate walls of rich leads; and from some mines more slate than quartz goes to the stamp-mill. It is found associated in the leads with calcite, felsite, mica, chlorite, with common, magnetic, and arsenical pyrites, with copper-pyrites, galena, and zinc blende. Crystals of gold have also been found, and gold imbedded in crystals of quartz, in cavities of leads.

There are yet other characters suggestive of true veins. Often there is a narrow band of crushed slate next the lead, called "gouge," on account of the ease with which it is extracted by a thin long pointed pick. Its fissile nature is probably due to disturbance at the time the lead was formed. Again, these leads are known to taper out, and what may be called their continuation to start in the side slate, and expand to the original thickness from beyond the termination of the quartz at first worked.

While many of the gold-bearing leads are regular and persistent for hundreds of feet and lie parallel with wonderful uniformity, a careful following shows local troubles. Rolls and barrels and offshoots have been mentioned, and also their apparent influence on the productiveness. Breaks and dislocations of the strata are not uncommon; and while many undoubtedly are of later age, some appear to be contemporaneous. A head or fault divides the Sutherland lead at Sherbrooke without shifting the strata; and on one side of it there are more bands and a greater thickness of quartz than on the other.

Another character, unmistakably that of a true vein, is occasionally met with in the "bedded" leads. For example, in the so-called Barton lead at Tangier, at one spot the writer saw in the middle of the quartz a flake of slate about 10 feet long and an inch thick. The flake had rough edges, and had evidently parted from the hanging wall; for a trail of fragments at its ends marked its course from a depression in the wall. Fragments of slate, too, are often found in the leads, lying in every direction; in parts films of slate give the leads a ribbon-like structure, and suggest a series of expansions of the fissures and successive depositions of quartz marked by the adhering films of slate.

As it is from mining experience that the weightiest arguments against the bedded origin of the leads can be adduced, fuller reference is made to matters that affect the mining than may seem warranted in a geological paper. There are yet a few observations worthy of note. The constituents of the leads are not uniformly mixed: in the Hay lead 60 ounces of gold were aggregated in one spot; and extended workings in the same lead failed to find elsewhere more than a few pennyweights of gold to the ton of quartz and calcite, the latter a principal component of the lead. The working portions of the leads are small, and the yield of gold not uniform. So far, experience does not encourage extended search beyond the limits of a working "streak" by sinking or driving levels; and the writer is not aware of the discovery in depth of a paying streak not known on the surface.

Relative Age of the Leads and Granite.

It has been suggested that the so-called granites which blot large portions of the Palæozoic belt are not intrusive, but are merely highly metamorphic rocks. That in every case they are so seems hardly compatible with structural characters observable, and which may here be briefly noticed. On traversing the country under review, the hill-tops are often seen denuded of all detrital matter save a few isolated boulders, and the junction of the granite with the sedimentary rocks is in many places exposed.

At Mooseland, for instance, exposures show the line of contact as clearly as would wooden models specially designed to do so; and there the following observations may be made:—Granite occupies the highest ground, presenting a curved margin, in part parallel and in part transverse to the strike of the bedded rocks, which are highly inclined and locally broken. Tongues and veins extend from the parent mass of granite between the opened strata; and in one about 2 feet wide there lies obliquely a thin slab of quartzite half an inch thick and 6 feet long, which has evidently fallen away from one of the walls. Another spot shows a larger slab, about 10 feet long and 1 foot thick, which has fallen forward into the body of the granite while the latter was still in a plastic state. Its original site can without doubt be ascertained by measurement. Parallel to a vein of pure quartz a vein of granite only half an inch wide, 200 feet from the main mass, demonstrates the plasticity, if not fluidity, of the granite; but whether it was derived from excessive local metamorphism or injected from below, is open to question. The sharpness of the broken edges and the locally disturbed condition of the beds along the line of contact certainly suggest the latter, while the crystalline structure of the protruding tongues seems to confirm it; for, as in a chilled casting, the crystals are coarse in the centre and fine next the walls, from more rapid cooling. The crystallization of the mass is, in spots, streaked and irregular near the sedimentary rocks;

and fragments of quartzite may be found imbedded in it. That the intense heat of the granitic mass affected the structure of the contiguous strata is evident from the development of andalusite crystals in the quartzite, and of garnets in the slates,—the former at Mooseland and near Fifteen-Mile Stream; and the latter close to the granite of Cochran's Hill, Sherbrooke, in the walls of gold-leads, and even imbedded in the quartz itself.

A most interesting spot bearing on the subject of this note is on the barrens near the west shore of Moose Lake, where a quartz-lead rising somewhat above the level of the containing quartzite is capped by granite and pierced by small tongues of granite, suggestive, if not conclusive, that the leads are of greater age than the granite.

Glaciation and the Leads.

Grooves and striæ on the surface of the rocks protected from further action by a covering of earth are common throughout the region. Glaciers, an ice-sheet, and icebergs have each their advocates to account for them; and the amount of denudation that they have occasioned is variously estimated. The labours of the gold-prospector have supplied some data which should not be overlooked in forming a conclusion on the subject. The experience of the gold-miner leads him, when he finds the "throw" of a vein, as he calls the float or shoadstones, to seek to the northward. He generally expects to find it within 100 feet of where the "throw" comes to the surface—on the hang of a hill, and where the cover is heavy, at a greater distance than where the surface is flat and the soil thin. In exceptional cases, where a rich throw has been found, trenches have been dug for many hundreds of feet, and every inch of the ground examined without discovering the lead. The so-called Rose lead at Montagu is still unknown, though the throw or drift of similar appearance, and supposed to have come from one lead, has been found to extend over 1000 feet of ground*. Another instance occurred this summer (1878) at Cariboo: large boulders of quartz, weighing in all some 40 tons, which were obtained from one spot, yielded largely, and great search was made for the lead from which they had been derived; but the exploring-trenches both to the north and south failed to find a lead. The boulders were found resting on the bed-rock, which at the particular spot where they were found was on a level with the surface, while about it the surface-soil was deep.

Boulders of other rocks have been traced to their source miles away. In the neighbourhood of Halifax the drift contains fragments of limestone from the Lower Carboniferous and of amygdaloidal trap from the Triassic of the Bay of Fundy, some sixty miles distant. A lump of iron-ore was found on digging a well at Hammond's Plains, of similar appearance and composition to that of the nearest known ore, that of Brookfield, thirty miles to the north. These instances are sufficient to show that while the drift has carried

* Since traced 2200 feet in the direction of the striæ, and a rich mine opened.

much of the "throw" or detached pieces of the rocks but a short distance, it has removed some pieces to very great distances. In general the drift is from the north—though, some prospectors say, on some hill-tops it is from the south, indicating the existence of counter-currents in the shallow waters, supposing the drift to have been due to a northern current and not to an ice-sheet. The angular shape and size of the fragments show that the disjointing force was not a comminuting one. It would further appear that the abrasion of the surface due to the drift was not extensive. On the turn of the Oldham anticlinal the surface is serrated, with the tops of the ridges alone planed off, and the general appearance suggests that the present contour was given before the ancient surface, broken by frost and weather, had its fragments torn away and a new surface formed by the attrition of blocks set in ice passing over it. In some cases the very blocks apparently that made the striæ have been turned over and expose their under surfaces fluted in a similar way to the surface of the bed-rock. Close to the Wellington railway-station a narrow band of rock may be seen slightly elevated above the general level and transversely crossed by striæ evidently of later origin than the displacement of the band; for the striæ are deeper in the band, and their continuations on the undisturbed surface do not take in for 2 or 3 inches from the elevated edge of the band.

Gold in Carboniferous Conglomerate.

At Gay's River the Carboniferous conglomerate is worked in a small way for the gold which is found mixed with the lower portion of the bed. In the "runs" or hollows of the slate the bed-rock is also removed to a depth of 3 or 4 feet for the gold contained in the backs or crevices of the slate. The gold is not very fine; and pieces weighing over a pennyweight are only occasionally found. Usually the surface of the grains is rough, not as though it were fresh from a lead, but rather as if each grain or piece of gold had been first smoothed by attrition and afterwards had fine particles attached to it.

The Total Yield.

Although of interest to the geologist and miner, the gold-fields of Nova Scotia are not of great importance. The annual yield of late years has only been about 13,000 ounces; the largest produce of any one year was 27,000 ounces. The gold obtained is noted for its fineness.

Discussion.

Mr. J. A. Phillips confirmed the views of the author as to the leads of Nova Scotia being true mineral veins.

Mr. W. W. Smyth stated that he thought the author of the paper had rendered a most useful service to geology in completely upsetting the theory (based on imperfect observation) of the bedded origin of the leads.

22. NOTES *on the* STRATA *exposed in laying out the* OXFORD SEWAGE-FARM, *at* SANDFORD-ON-THAMES. By EDGAR S. COBBOLD, Esq., F.G.S., Assoc.M.Inst.C.E. (Read February 25, 1880.)

THE strata under consideration consist of the upper and middle members of the Oxford Oolites, together with the Kimmeridge Clay; and though little novelty can be expected in a paper on such well-studied and readily accessible deposits, it is hoped that at least one or two important facts may be put on record.

The area treated of is only about $1\frac{1}{2}$ mile in length from east to west, and one mile from north to south. It is situated about 4 miles S.E. of Oxford, on the south side of the Thame and Aylesbury branch of the Great Western Railway, and east of the turnpike road from Oxford to Dorchester & Henley. Though small, it presents some interesting variations in the strata.

Previous to the laying-out of the 350 acres selected for sewage-irrigation, a number of trial-holes were dug to ascertain the nature of the subsoils and substrata, and subsequently a complete system of land-drainage was carried out, necessitating the digging of trenches from 3 to 8 feet deep and not more than 66 feet apart all over the land. There was therefore ample opportunity for obtaining accurate information on the superficial development of the various strata.

At Headington a generalized section of the beds appears to be somewhat as follows:—

	ft.
Kimmeridge Clay.	
Coralline Oolite .... (say)	15
Coral Rag .... (say)	15
Sand	2
Shell-bed	3
Calcareous Grit	60
Oxford Clay.	

In the neighbourhood of Sandford and Littlemore, the Coral Rag and part of the Coralline Oolite are replaced by marls which are in places full of small oysters and *Serpulæ*, with a few other fossils, but show no trace of corals*. These marls may be best seen in the railway-cutting west of Littlemore Station, where they have been thrown into long undulating curves, as shown in the section (fig. 1), and have been traced to a distance of about one mile on all sides.

Northward they may be seen at an old quarry on the top of Rose Hill, Iffley; westward, at a small quarry behind the village of Kennington, on the other side of the Thames valley; southward, in Sandford Hill; eastward, in the side of a small pond near the

* One specimen of *Thecosmilia* has been obtained on the sewage-farm, from the lowest bed of the marls.

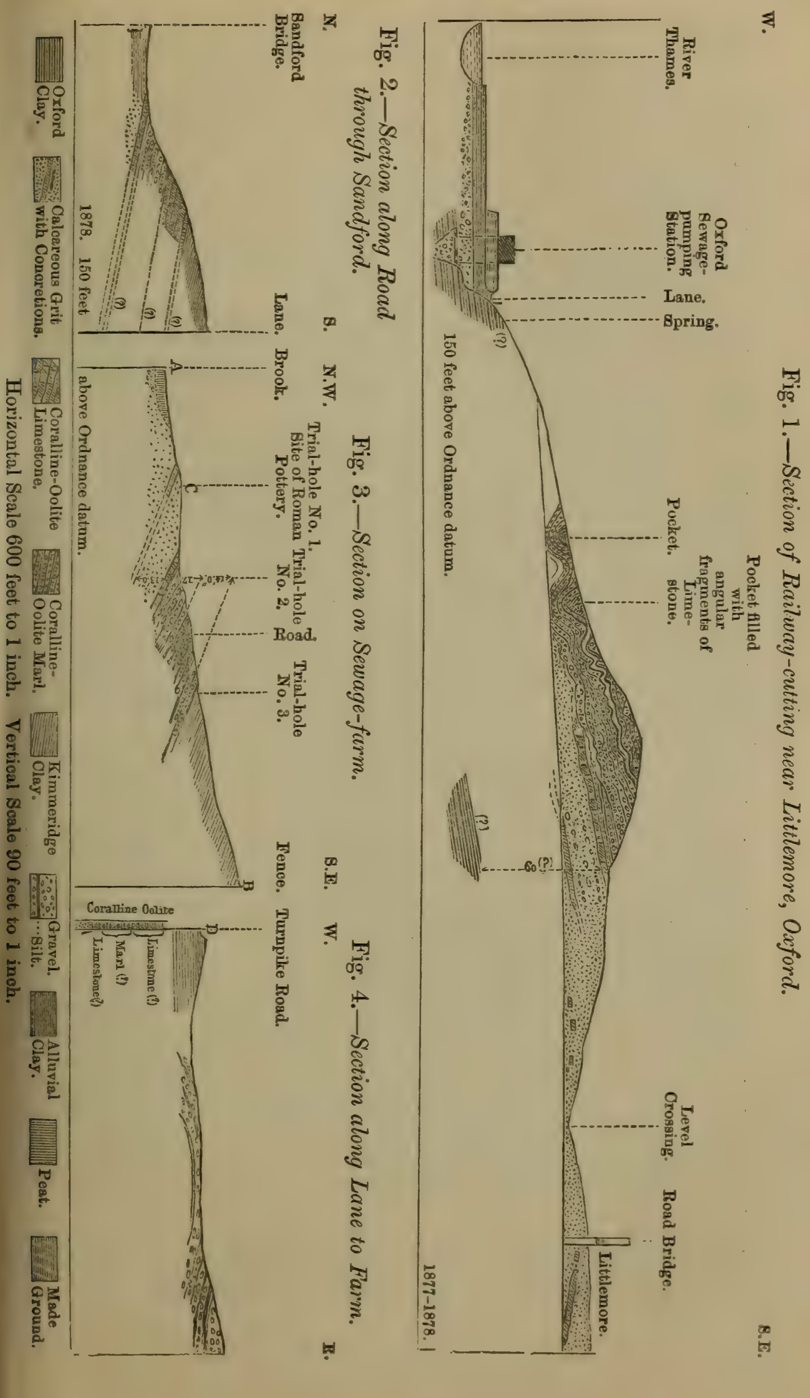


Fig. 1.—*Section of Railway-cutting near Littlemore, Oxford.*

Fig. 2.—*Section along Road through Sandford.*

Fig. 3.—*Section on Sewage-farm.*

Fig. 4.—*Section along Lane to Farm.*

Horizontal Scale 600 feet to 1 inch. Vertical Scale 90 feet to 1 inch.

crossing of the railway by the cross road from Cowley to Garsington; and south-eastwards over a considerable portion of the sewage-farm.

A vertical section of the beds in the railway-cutting is given in fig. 5. Here there are about 17 feet of alternate layers of marl and clay, 37 in number and varying from 2 feet to 3 inches in thickness. At the base the marl seems to graduate into limestone 1 foot 3 inches thick, which is succeeded by a bed of fine sand 2 feet thick with fragments of shells and spines. Below this is a very compact and hard limestone very full of shells, also 2 feet 6 inches thick. It was from this bed that most of the stone was quarried of which the bridges on this part of the line were built.

This is followed by the fine soft sand of the Calcareous Grit, which contains very few fossils, and several layers of concretions of sandy limestone. At 12 feet 9 inches below the top of this sand is a much more continuous layer of similar stone, which has been found in many places on the sewage-farm.

In the longitudinal section of the railway-cutting (fig. 1) the strata are seen to be inclined at a slight angle westwards; but the actual dip and strike have not been ascertained. At the Littlemore Station, however, the inclination is reversed, and there seems to be a slight anticlinal axis somewhere near the level crossing west of the road; but this may be apparent only, as the line of section necessarily follows the curvature of the railway.

From the west end of the cutting the section is prolonged to the river Thames, passing through the site of the sewage-pumping station, the foundations of which came in a deep irregular depression in the surface of the Oxford Clay, suggestive of an old river-course, but at a lower level than the existing one.

The level of a spring on the side of the hill is also shown, as giving a probable indication of the height to which the Oxford Clay rises on this side of the valley.

No strata corresponding to the Coralline Oolite of Headington are to be seen in this cutting; but apparently in the folds of the marls on the west slope of the hill there are some pockets containing angular fragments of limestone. Similar pieces may also be seen scattered over the surface of the hill above the cutting; so that possibly it might be met with at a higher level.

In laying the sewage-pumping main along the road up Sandford Hill an interesting section was exposed, a sketch of which is given in fig. 2. At the foot of the hill the shell-bed (here very full of *Gervillia*) and its accompanying sand were found. These were succeeded by marls having a vertical height of about 15 feet, of a bluish grey colour, unlike those in the railway-cutting and on the farm, which are more or less white. As the road has been made in a cutting in the side of the hill, the change of colour may be due to the oxidizing effect of the weather not having yet penetrated so deep.

Above the marls was a thickness of about 12 feet 6 inches of very hard fine-grained limestone in 3 or 4 layers with hardly any fossils, evidently answering to the Coralline Oolite of Headington. Above

VERTICAL SECTIONS.

Fig. 5.—*Railway-cutting near Littlemore.*

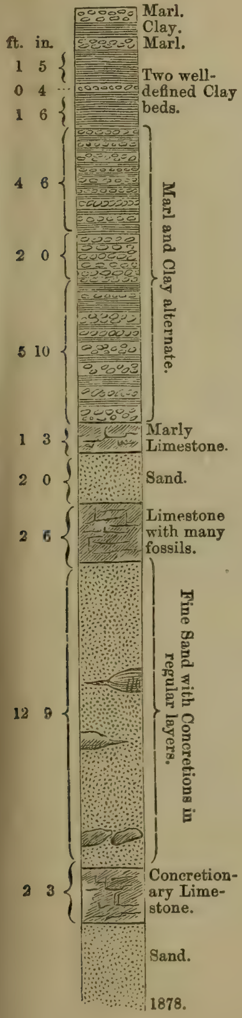


Fig. 6.—*Quarry on Sewage-farm.*

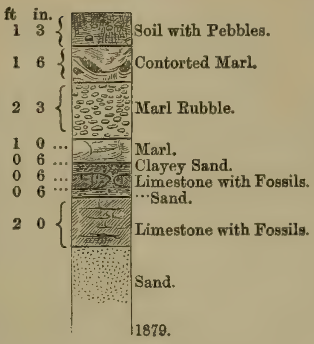


Fig. 7.—*Trial-hole No.* 3.

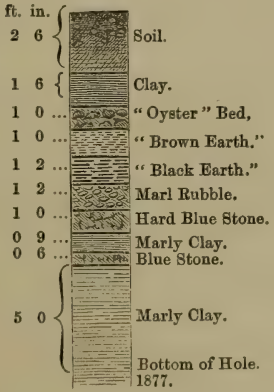


Fig. 8.—*Trial-hole No.* 1.

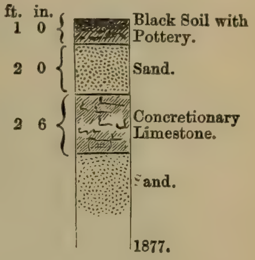


Fig. 9.—*Trial-hole No.* 2.

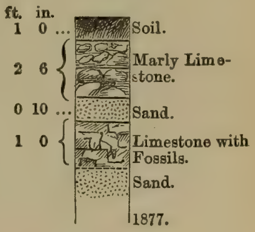
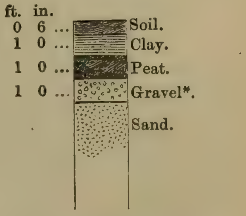


Fig. 10.—*Trial-hole No.* 4.



* Detritus of Marl (small Oyster-shells).

Scale ⅛ in. to 1 foot.

this, again, was a stratum of very sandy limestone 2 feet 6 inches thick, suggesting a trace of the Upper Calcareous Grit.

Then followed compact Kimmeridge Clay, containing vertebræ of *Pliosaurus* and quantities of crystals of selenite, also at the end of the section near the surface a marly layer with some good specimens of *Rhynchonella inconstans*. The inclination of the base of the Kimmeridge Clay was ascertained to be 1 in 60 in the direction of the road (S.S.E.), which would give a thickness of 20 feet at the end of the section.

At the junction of the Kimmeridge Clay with the Coralline Oolite was a peculiar, bright-red, earthy layer from 4 to 6 inches thick.

A section at right angles to this along the lane leading from the south end of fig. 2 to the farm was also exposed, and is given in fig. 4; but it was too shallow in the lowest part of the road to show the junction of the clay with the marls, which, it may be noticed, again show long undulations, and rise to a higher level than the clay, implying either a very sharp bend in the strata or a fault through the lowest point of the section.

On the west side of the sewage-farm is a quarry sunk through the base of the marls to the shell-bed below, which is used for road-making. A vertical section here (fig. 6) shows the shell-bed and sand resting on the Calcareous Grit, with the marls above. Where the latter are within 3 feet of the surface they are much contorted and mixed up, so as to lose their original bedding, and here and there are balls or nodules of brown clay (probably foreign to the marls) surrounded by concentric layers of darker and lighter material.

As considerable quantities of stone were required for making roads, it was hoped that the same bed might be found on the other side of the farm; and several trial-holes were sunk with this special object.

At no. 1 (fig. 8) a layer of concretionary stones, similar to that in the sand of the railway-cutting at 12 feet 6 inches below the top of the Grit, was found.

At no. 2 (fig. 9) the shell-bed is shown, but here it has diminished in thickness to about 1 foot, and as there was a considerable quantity of water in the sand, it was not worth working.

At no. 3 (fig. 7) it was hoped that the Coralline Oolite would be found as in Sandford Hill; but on sinking through the clay, marl was at once found, with only two layers of stone 1 foot and 6 inches thick respectively. It was also of a blue colour, similar to that in Sandford Hill.

Subsequently a small quarry was opened (at C, fig. 3), close to trial-hole no. 1, which exposed a quantity of Roman pottery. Several kilns have since been found here, and in order to show the proximity of the Kimmeridge Clay, the section (fig. 3) was constructed. It has never been wholly exposed, and is therefore somewhat hypothetical as to inclination of strata; but it was proved in many places by subsequent excavations, and may be taken as tolerably correct.

The inclination was arrived at by setting off below the shell-bed in trial-hole no. 2 a depth of 12 feet 6 inches, which was supposed to give the surface of the concretionary stone shown in no. 1. In order to prove this to some extent, heights of 15 feet and 14 feet 6 inches were set off above the base of the marl, corresponding to the observed thicknesses in Sandford Hill; and lines drawn through these points parallel to the assumed bed of rock in the Grit represented the tops of the marl and limestone, if present. This construction showed that instead of the Coralline Oolite being denuded, as was at first supposed when marl was found under the clay of trial-hole no. 3, it had entirely changed its character in the short distance (1 mile) from Sandford.

Also, as the upper line intersects trial-hole no. 3 very nearly at the depth where marl was found, there can be little doubt as to the general accuracy of the section.

As coral-bearing strata are found on either side at Headington and Cumnor, there seems to have been here a gap in the reefs, which is filled with a more clayey deposit; and it is suggested that the influx of clay may have been due to the muddy discharge from some river which might hinder or altogether check the growth of corals, while it was favourable to that of oysters. The width of the marl deposit cannot be more than 3½ miles, that being the distance between Headington and Cumnor; so the supposed river cannot have been very large or very far off. Further, the rapid thinning-out of the Coralline Oolite of Sandford Hill (within possibly a length of ½ mile) points to a further constriction in the river's influence, which (if reliable) gives a possible clue to the direction from which it flowed, viz. S.E. It seems therefore probable that the Palæozoic rocks known to exist beneath London may have been above water in the later Oolite period and have had considerable extension to the S.W. and E.

A considerable portion of the sewage-farm is upon the Calcareous Grit; and the many trenches have yielded the following few fossils:—

Ammonites plicatilis.
—— cordatus (?).
Modiola bipartita.
Gervillia aviculoides.
Pecten vagans.
Perna, sp.
Ostrea dilatata (large).
Ostrea gregaria.
——, sp. (small).
Serpula, sp.
Sponge?

Hemipedina marchamensis, from Heyford Hill Lane, Littlemore.

Many beds of rock were met with in the sand; but no continuous section was obtainable. The lower beds seemed hard and flaggy with oolitic granules on the surfaces; those nearer the top frequently presented irregular sponge-like shapes, and were very soft and friable; while the upper beds were generally concretionary and more compact.

The bottoms of the small valleys which intersect the farm are filled with peat from 4 to 6 feet deep, in which have been found Roman pottery (at 3 feet), freshwater shells, bones of deer, domesticated pig, cow, horse, and dog. Under the peat, patches of gravel of a very local character are found, quite unlike that in the Thames valley.

At trial-hole no. 4 (fig. 10) this gravel is composed almost entirely of small oyster-shells derived from the marl. The peat here is covered with a superficial clay, probably brought down by atmospheric denudation from the Kimmeridge Clay on the hill near by.

It is hoped that these notes may not be altogether without interest, as they may preserve some account of the various sections exposed in the laying-out of the Oxford sewage-farm, which have since been covered up, and are not likely to be again accessible.

Discussion.

The President said the paper was an exceedingly interesting and useful one, as placing on record what had been done.

Prof. Prestwich said the area, though small, was extremely interesting, as the sections differed so much from those of Headington and Cumnor. The evidence, however, was perhaps too small to found a theory upon.

Mr. Hudleston said that clay was not unfrequently mixed with the Coral Rag. Probably that clay might come from the source which supplied the clays of the contemporaneous portions of the great Pelolithic formation of the Fenland.

Prof. Seeley said that north of Oxford the Coral Rag became split up into clays; the fossils changed with this.

The President said the specimen obtained of *Hemipedina marchamensis*, and also some of the other fossils were remarkably fine. As the sections were closed, such a record of the facts observed as was furnished by this paper was of much importance.

23. *On the Genus* Pleuracanthus, *Agass., including the Genera* Orthacanthus, *Agass. and Goldf.*, Diplodus, *Agass., and* Xenacanthus, *Beyr.* By James W. Davis, Esq., F.S.A., F.G.S., &c., Hon. Sec. Yorkshire Geological & Polytechnic Society. (Read January 21, 1880.)

[Plate XII.]

Hitherto specimens of *Pleuracanthus* have not been discovered in this country which would serve to illustrate the general characters or zoological position of this genus of fossil Fish. Teeth of *Diplodus*, almost invariably associated with the spines named *Pleuracanthus*, Ag. and *Orthacanthus*, Ag., are found in all the great coal-fields. In Staffordshire, Scotland, Lancashire, and Yorkshire, wherever fish-remains are found, there is some proportion of specimens of these genera. All the examples recorded are from the Coal-measures.

Though in England we have only the teeth and spines fossil, in Germany and Bohemia several examples have been discovered in which the whole of the fish is preserved. These specimens appear to be higher in the geological series, and have been relegated to certain passage-beds between the Coal-measures and the Permian, and to the Permian rocks themselves.

The ichthyodorulite *Pleuracanthus lævissimus* was described by the late Prof. Agassiz, in his 'Recherches sur les Poissons Fossiles,' from an imperfect specimen obtained from the coal-shales of Dudley. On page 330 of the same classical work, whilst discussing the "défenses des Raies," a second spine is mentioned as somewhat resembling *Pleuracanthus*, and, in all probability, related to it. It was named *Orthacanthus cylindricus*, and is figured in the third volume, plate 45. figs. 7–9; but the description was deferred to a supplementary volume, which, unfortunately, has never been written. At the same time that these spines were discovered, there were also found a number of fossil teeth, which were described and figured by Prof. Agassiz as *Diplodus gibbosus*.

In 1847, Goldfuss* described a very fine specimen showing the form of the head, vertebral column, pectoral and ventral fins, and the spines still in position, imbedded in a cartilaginous mass immediately behind the occipital region of the head. The spine in this instance is round, has a median ridge on the dorsal aspect; and on each side of the ridge, separated by a narrow groove, is a row of denticles. This is clearly the *Orthacanthus* of Agassiz. The fish was named by Dr. Goldfuss *Orthacanthus Dechenii*.

In the following year, M. Beyrich† described and discussed the relationship of a fish resembling in all essential respects the one described by Goldfuss, except that the spine, instead of being round, like *Orthacanthus*, "is flattened before and behind, and has on each

* Beiträge zur Fauna des Steinkohlengebirges: Bonn, 1847.

† Bericht der königl. preussischen Akademie der Wissenschaften, 1848, p. 24.

side rows of sharp, short, hook-shaped, backward-pointing teeth." This is evidently the same as Agassiz's genus *Pleuracanthus*: but Beyrich gives it the new generic name *Xenacanthus*, remarking that the *Orthacanthus Dechenii* of Goldfuss must be given up in favour of *Xenacanthus*, and that though the name *Pleuracanthus* of Agassiz has priority, and would have been well suited to embrace this new fish, it was too well known as the name of a spine only.

In 1855, Sir Philip de M. Grey-Egerton, at the Glasgow meeting of the British Association, pointed out that the spines of *Pleuracanthus* and *Xenacanthus* and the *Diplodus*-teeth all belonged to the same genus of fossil fish; and two years later, in the 'Annals and Magazine of Natural History,' the same ichthyologist, considering publication as the test of priority, enforces the claim of the genus *Pleuracanthus*.

Prof. Rudolph Kner*, in 1867, in an elaborate paper on the genera *Orthacanthus*, Goldf., and *Xenacanthus*, Beyr., after a careful examination of all the Bohemian specimens available, arrived at the same conclusion as to their identity that had been put forward twenty years previously by Beyrich. Notwithstanding this, the specimens which have been figured in illustration of his views embrace examples with spines of both the *Pleuracanthus* and *Orthacanthus* type.

The principal difference between the genera *Orthacanthus* and *Pleuracanthus* in the type specimens figured by M. Agassiz lies in the position of the two rows of denticles or barbs. Both spines are figured as straight, and have an internal cavity open at the base and extending far towards the point. In *Pleuracanthus* the denticles are situated on the lateral faces of the spine, the two rows being as widely separated as possible; whilst in *Orthacanthus* they are very close together and extend along the posterior face. A reference to the series of spines described in the following pages, along with those already described and figured in the memoirs of the State Survey of America, will prove that the difference in the relative position of the rows of denticles must either be of small generic importance or that many new genera will have to be formed for their accommodation. Almost every intermediate stage between the two forms is now known; the denticles extend at every angle between the sides and back of the spine. After careful consideration of the specimens, one is led to the more natural conclusion that they have been borne by fishes having characters of a single generic type, and that they should consequently be included in the genus *Pleuracanthus*, Agass.

The teeth of *Diplodus* have hitherto been found associated indiscriminately with the spines of *Pleuracanthus* and *Orthacanthus*; and there has been no generic difference detected in the somewhat numerous species of *Diplodus*-teeth: this renders the probability of the spines belonging to different species of the same genus very great, and stamps their relationship almost with certainty.

A short time ago I had the pleasure of describing two new species

* Sitzungsberichte der kaiserl. Akad. der Wissensch. Band lv. 1867.

of the genus *Compsacanthus*, Newb., to this Society *. The general characters of that genus suggest a close proximity to *Pleuracanthus*: the terminal opening and the internal cavity, the straight, acuminate, dagger-shaped form of the spine, and the close, compact, fine-grained structure of the bone closely resemble *Pleuracanthus*; its method of attachment to the body, and its position immediately behind the head, were, in all probability, similar in the two genera; in general appearance *Compsacanthus* presents a close approximation to some of the Pleuracanths, its only distinguishing feature being its possession of a single row of denticles along the posterior face.

The genus *Pleuracanthus* appears to have been composed of fish differing in many respects from any known to exist at the present time. In external form they were formidable, somewhat flat-shaped fish, with a large head, large broadly expanded pectoral fins, gradually tapering body, and large flat abdominal or ventral fins. The tail is not well known, but appears, from imperfect impressions preserved in some of the German strata, to have been unilobate, with the caudal fin extending along the dorsal and ventral aspects, and encircling the end, somewhat after the manner of that of an eel. Immediately behind the occipital region of the head extended the defensive spine. The latter was probably one fourth or one fifth of the entire length of the fish. The body may have been covered with minute pointed granulations or shagreen; but in the majority of the specimens the skin appears to have been without scales or other protection.

The head was massive, much depressed, and nearly round in form. Extending in the form of a half circle along the anterior margin, the jaws constitute a prominent feature. They were armed with comparatively large, sharp, three-pronged teeth, which extended, row behind row, from the circumference towards the centre of the large mouth, very closely approaching the character and formation found in the Sharks of the present day. The jaws and various constituents of the cranium appear to have consisted of cartilage with a multitude of closely approximating ossicular centres. In the fossil state this conformation has a very characteristic and pretty appearance; it was happily compared by Beyrich to a species of mosaic. The little bony centres are square in form with the corners rounded off, and shine with a bright and lustrous black appearance. Many of the specimens from the Cannel Coal of Yorkshire are impregnated with iron, which, in the form of pyrites, has replaced the cartilaginous parts, thus encircling the black glittering enamel-like specks of bone with a golden setting.

Possibly owing to the soft and easily compressed character of the skeleton of the head, the orbits in the fossils are not distinguishable, and the position and size of the eyes are not known. There are indications, however, which might lead to the inference that they were widely separated, and situated about half the diameter of the head from the extremity of the snout. In the specimen described by Dr. Goldfuss there are two conical depressions, pointing anteriorly out-

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 62.

wards, which may have been connected with the nostrils. Dr. Kner considers that there were certainly four or five gill-arches, which were furnished with a few long teeth. The gill-arches were attached to the substance of the hyoid bones, their union with the shoulder-girdle being similar to that in the Squalidæ. Immediately behind the large jaws the head seems to have been contracted in width. From the centre of this part the spine emerged. It was not connected by any articulation, but appears to have been simply implanted in the cartilaginous mass of the occipital region. In all the specimens where the spine is present, it is found lying in close proximity to and along the dorsal surface of the fish.

In the vertebral column the vertebræ were cartilaginous, except the apophyses to which the ribs were attached; these appear to have been more or less bony. The ribs were short and somewhat rudimentary, broad at the base for articulation, and ending in a point. Immediately behind the spine there originated a dorsal fin, which extended along the back to the caudal extremity. Besides the spinous processes attached to the vertebræ and the spinous rays which constituted the fin, there were two series of interspinous bones, the latter articulated in the usual manner.

This arrangement probably extended a short distance beyond the abdominal fin. The interspinous bone next to the spinous process of the vertebræ then disappears, the second one being continued nearly to the caudal extremity of the body. A fin also extended along the ventral surface of the body, and, joining the dorsal one, formed a single-lobed tail.

The pectoral arch was large and strong. Dr. Goldfuss* describes it as being built up on either side of an inner bone composed of a single piece, which, on the hinder part, is bent on its outer edge in the shape of a knee. This edge is beset with fin-rays. The anterior ones are very short and thin; those following are long and thick. Just before the knee-shaped angle springs a strong, distinctly jointed ray. It carries on its outward side seventeen thick strong fin-rays, which become fibrous towards the end, and on its inner side a number of smaller and closer fin-rays. It is not clear by what means the knee-shaped bones were attached to the remaining bones of the shoulder-girdle. In a well-preserved specimen of the pectoral fin from the Cannel Coal at Tingley, all the larger fin-rays are jointed, the joints between each articulation averaging about half an inch in length. The fin has probably belonged to a much larger fish than the one described by Dr. Goldfuss. All the fin-rays were semicartilaginous, with innumerable minute centres of ossification.

The pelvic arch was constructed on a similar basis to the pectoral one. A broad, short, knee-shaped bone sprang from the vertebral column; and to this was attached an articulated primary ray, as in the pectoral fin; but whereas in the latter small rays sprang from the inner side of the primary ray, in the ventral fin only the outer portion supported fin-rays. Dr. Kner describes the pelvic bones as forming a ventral shield studded with hook-like appendages. These

* *Op. cit.*

he considers may have served a similar purpose to that of the claspers in cartilaginous fishes or the sheat-fishes. In some specimens they are absent; and these he concludes were female fishes.

The zoological affinities of this genus have been the subject of much careful research. Prof. Agassiz considered it as representing a fossil Ray nearly related to *Trygon*. Dr. Goldfuss consigned the genus to the Selachians, from its resemblance to *Squatina*; and, more recently, Dr. Kner has contended that it constitutes a distinct order between the Selachians and the Teleosteans, having many features in common with each, and forming an intermediate link between the cartilaginous and bony fishes.

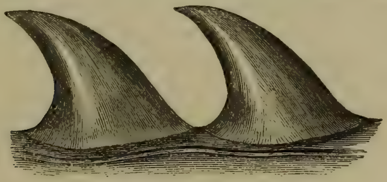
PLEURACANTHUS, Agassiz (Davis).

Spines more or less circular in section, with an internal cavity, terminal at the basal extremity, extending towards the apex; straight or slightly curved, and gradually tapering to a point; surface of the spine, where not denticulated, smooth or finely striated. Implanted portion of base short, with thinner walls than the exposed part of the spine. Along some part of the surface there extend two rows of denticles; these may be widely separated and lateral, they may extend in close proximity along the posterior surface of the spine, or the two rows may occupy any intermediate position between the two specified.

1. PLEURACANTHUS LÆVISSIMUS, Agass. Fig. 1.

Spine 8 or 9 inches long, ·6 to ·8 of an inch in largest diameter at the base, tapering evenly to a fine point. Straight, oval in section, with an internal cavity extending from the base to within a short distance of the point. Anterior and posterior faces smooth or finely striated; their lateral junctions are armed with a row of acuminate denticles (fig. 1), strongly curved towards the base, with an

Fig. 1—*Pleuracanthus lævissimus*, Ag.



Denticles of spine, enlarged.

inclination towards the posterior face of the spine. Each denticle occupies about ·1 of an inch. Near the point they are smaller, and at the opposite extremity somewhat larger. They extend from the point along two thirds the length of the spine.

M. Agassiz, who described this genus and species from an imperfect specimen obtained from the coal-shales near Dudley, lays considerable stress on the presence of a large groove or channel extending along the inferior face of the spine. In the several specimens in my own cabinet from the Lower and Middle Coal-measures of Yorkshire, there is no evidence of such a groove; the anterior and posterior faces are, as nearly as possible, one the counterpart of the other. The upper part of the spine was strong, the internal cavity very small; and the specimens remain uncrushed. The lower part of the spine was thinner, and the cavity proportionally larger, the result being that the walls of the base are frequently crushed together and broken. It appears probable, judging from the figure of *Pleuracanthus* in the 'Poissons Fossiles,' that the basal portion of the spine was crushed in this manner, and misled M. Agassiz into supposing that there was a deep groove extending along the spine. Examples from the Staffordshire Coal-field, probably from the same stratum from which M. Agassiz's specimen was obtained, fail to exhibit any traces of this groove.

Locality. L. C.M. near Halifax, and M. C.M. at Tingley.

2. PLEURACANTHUS ERECTUS, sp. nov. Fig. 2.

Spine straight, 3·5 inches long, ·4 inch wide at the base, converging in straight lines to an acute point. Oval in section; the transverse diameter one third greater than that between the posterior and anterior faces. An internal canal traverses the spine nearly its whole length; near the base it is oval in form, and the walls are thin and crushed; thence the cavity contracts and becomes circular, occupying the centre of spine. Externally the anterior and posterior rounded faces are covered with longitudinal striations; and a number of small pittings are studded indiscriminately over the surface, sometimes on the ridges, at others in the furrows. At the junction of the anterior and posterior faces the lateral edges are produced, and form a series of blunt compressed projections or denticles. They extend fully three fourths the length of the spine, and are from 22 to 24 in number on each side; they are ornamented similarly to the general mass of the spine.

Fig. 2.

Pleuracanthus erectus, Davis.

Spine, nat. size.

Locality. Cannel Coal, Tingley (M. C.M.).

P. erectus is a particularly straight example of the genus; and from this character I have ventured to derive its specific name. In general form it is somewhat similar to *P. lævissimus*, Ag.; but it is different in almost all the details. It is more elegant-looking, and converges from the base straight to the point on all sides. Its denticulation in no way resembles that of *P. lævissimus*, excepting in its lateral arrangement. The teeth are broad at the base, widely separated, and very blunt-pointed; in *P. lævissimus* they are closely set, long, and acuminate; the spine is less than half the size of that of the latter species.

3. Pleuracanthus tenuis, sp. nov. Pl. XII. fig. 1.

Spine remarkably long in proportion to the diameter; the basal and apical extremities are wanting; when perfect, it probably measured 6 inches in length. It is ·2 inch in diameter. The basal half of the spine is rotund in section; on the remaining portion the anterior and posterior faces are depressed, and their connexion with the sides forms a right angle, so that the form of the spine nearly approaches a square (fig. 3). Extending along the upper half

Fig. 3.—*Pleuracanthus tenuis*, Davis.

Section of spine, nat. size.

of each lateral face is a row of blunt denticles tipped with bright ganoine. The surface is covered with fine longitudinal striations and a great number of minute punctures, which together give it a reticulate appearance. There is an internal cavity, wide and round at the base, and smaller near the apex. The cavity extends the whole length of the part preserved. The spine probably converged to a point when perfect.

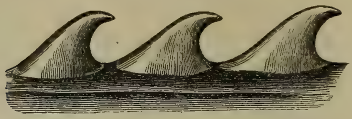
Locality. Bone-bed, Better-bed Coal, Clifton near Halifax (L. C.M.)

Pleuracanthus tenuis is a sufficiently peculiar species; the great length, small diameter, and slightly curved form are characteristics which at once distinguish it from all other species having the denticles arranged on the opposite lateral faces of the spine. It very nearly approaches in form the spine of the recent *Trygon*, the body of the spine being nearly square in section, and tapering very little until the apex is reached. The teeth in the recent form are long, pointed, recurved towards the base, and extremely close together; in the fossil one they are rather widely separated, broad at the base, and end in an obtuse point. It is, further, the only species having lateral rows of denticles which is curved. It is not an uncommon occurrence to find spines approaching more or less to the form *P. cylindricus* (Ag.)—that is, with the teeth on the posterior aspect, which are curved. Several examples are known both in this country and America, but none, so far as I know, of the *P. lævissimus* type.

4. Pleuracanthus pulchellus, sp. nov. Pl. XII. fig. 2.

Spine small and straight, 1·5 inch in length, and ·1 inch broad at the base. Its breadth, for about three fourths the length is nearly uniform; it then becomes rapidly acuminate, and ends in a point. Anterior and posterior faces smooth and considerably depressed, the diameter from back to front being equal to half the transverse diameter. An oval cavity extends from the base internally. The part of the spine implanted is small, its walls thin and fre-

Fig. 4.—*Pleuracanthus pulchellus*, Davis.



Denticles of spine, enlarged.

quently crushed; the upper two thirds of the length are armed on each lateral face with about twenty exquisitely beautiful little denticles; they are firmly attached, recurved towards the base, and culminate in an acute point (fig. 4).

The beauty of this little ichthyodorulite has suggested its specific name.

Locality. Cannel Coal, Tingley (M. C.M.).

It is possible that the small spine, *P. pulchellus*, may be the immature form of some other species; but I have at present no evidence that such is the case. I have in all half a dozen specimens; and they are all of the same size within the eighth of an inch. It most resembles *P lævissimus*, Ag. There is a considerable similarity in the denticulation of this form and the type of Agassiz; at the same time the method of insertion in the mass of the spine is different. If these were young and immature specimens, we ought also to find them of other and intermediate sizes; but hitherto such has not been the case. It is possible that further evidence may be found; but for the present it will be better to distinguish these spines as a distinct species.

5. Pleuracanthus alternidentatus, sp. nov. Pl. XII. fig. 3.

Spine straight, 2·5 inches in length when perfect, ·2 inch in greatest diameter at the base. From the base the diameter of the spine decreases until it ends in a blunt point; the internal cavity is terminal, circular, and comparatively small; external surface striated longitudinally; anterior and lateral faces circular in section; the posterior depressed and about the width of the diameter of the spine (fig. 5).

Fig. 5.—*Pleuracanthus alternidentatus*, Davis.

Section of spine, nat. size.

The angle formed by the junction of the lateral and posterior faces is set with seven or eight widely separated obtuse denticles, extending from the apex along one third of the length of the spine. They present the peculiarity of being inserted alternately, the denticle of one side being opposite to the depression on the other. From this characteristic I have applied the *nomen triviale* as above.

Locality. Coal-measures, Middleton near Leeds. Leeds Literary and Philosophical Society's Museum.

P. alternidentatus is more nearly related to *P. alatus* than to any other. It is, however, easily distinguished by its more robust appearance, the diameter being greatest between the anterior and posterior surfaces, whilst in *P. alatus* the transverse diameter is greater. The walls of the spine in this species are much thicker and stronger than in *P. alatus*. The point of most divergence consists perhaps in the widely separated and alternate denticles.

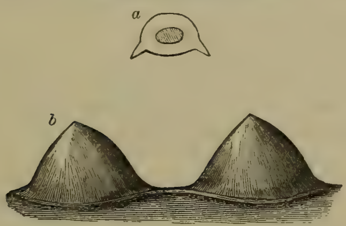
6. Pleuracanthus planus, Agass. (sp. indet.).

In the 'Poissons Fossiles,' tome iii. p. 176, M. Agassiz records a spine of *Pleuracanthus*, to which he has appended the specific name *planus*; it is said to be from the Coal at Leeds. Sir Philip Egerton, who possesses the type of *P. planus*, writes me "that it is about ½ an inch in length, the basal end being absent; there are six or seven strong hooklets on each side imbedded in the matrix. The exposed surface is quite smooth and flat."

7. Pleuracanthus alatus, sp. nov. Pl. XII. fig. 4.

Spine. Length 2·2 inches, breadth ·2 inch; the general form is straight. A slight appearance of curvature is given by the anterior face curving from the base to the apex, whilst the posterior is straight. From the basal end to the middle the spine has been crushed; it appears to have been uniform in diameter; from mid-length to the apex it becomes gradually smaller, and ends in a fine point. It is uniformly striated on the anterior and posterior surfaces; the intermediate furrows are frequently broken into a succession of pittings, especially the lower parts. There is an internal

Fig. 6.—*Pleuracanthus alatus*, Davis.



a. Section of spine, nat. size. *b.* Denticles, much enlarged.

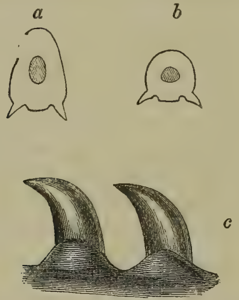
cavity, open and large at the base. In section the posterior face forms a much-depressed curve, the anterior curvature forming a semicircle above it (fig. 6 *a*); the lateral angles formed by the junction of the two are ornamented or armed with a row of denticles (fig. 6 *b*), numbering ten on each side. They extend from the point ·8 of an inch. The denticles are broad at the base, closely set and short, terminating obtusely, with a slightly trenchant edge parallel to their longitudinal axis. Those nearest the apex of the spine are less produced than those lower down.

Locality. Cannel Coal, Tingley (M. C.M.).

8. Pleuracanthus robustus, sp. nov. Pl. XII. fig. 5.

Spine. Length 3·5 to 4·5 inches. Breadth, about mid-length, ·4 of an inch. From the middle the diameter of the spine becomes smaller in each direction; towards the apical extremity it contracts rapidly, and terminates in an obtuse point; the base is reduced to three fourths the largest diameter. The spine is straight along the dorsal side; the opposite one slightly curved. The lateral and anterior surfaces are covered with fine but very decided longitudinal furrows, numerous towards the base, and disappearing, without anastomosis, towards the apex. The general form of the spine in section (fig. 7 *a*, *b*) is rotund, the lateral faces being produced outwardly so as to meet the more depressed curvature of the dorsal aspect. The dorsal surface is wide, embracing nearly one third of the entire circumference of the spine. It is produced so as to form a large median ridge; and along the centre of this there are a number

Fig. 7.—*Pleuracanthus robustus*, Davis.



a. Section of the spine near the base. *b.* Section nearer the point.
c. Denticles, enlarged.

of small punctures, which occasionally coalesce and form a slight groove. On each side of the median ridge is a proportionally deep furrow. The angles formed by the outer edges of these furrows and the sides of the spine are armed with a series of large closely-set acuminate denticles (fig. 7 *c*). They extend from the surface of the spine ·1 of an inch, being nearly one half the diameter of the spine they are very strongly implanted, and recurved towards the base The outer surface of the denticle, *i. e.* the one forming the largest curve, is produced in the form of a minute carina or keel. There are about twenty denticles, extending rather less than one half the length of the posterior face. The internal cavity is round, and, except at the base, is comparatively small; it is in the centre of the spine. The walls of the cavity are thin where it has been imbedded in the muscles of the flesh; they gradually gain in thickness and strength until the cavity ends in a point about 1 inch from the distal end, the remaining part being solid.

The preceding species, viz. *Pleuracanthus robustus*, *alatus*, and *alternidentatus*, possess features in which, speaking broadly, they are somewhat similar to each other. Whilst, however, they possess this general similarity, they differ considerably in detail. *P. robustus* is a larger and stronger spine than either of the others; it has quite double the number of denticles on its posterior surface; and the space between the two rows of denticles is produced so as to form a very distinct median keel; it is deeper from back to front; and the internal orifice is proportionally small. *P. alatus* is a broader spine; its diameter is greatest from side to side; whilst *P. alternidentatus* is as nearly round as possible—neither of the latter two possessing a posterior median keel. The posterior teeth differ in each of the species. In *P. robustus* the teeth are long, arched, and terminate in a fine point; they present the appearance of being implanted in alveolar cavities. The denticles of *P. alatus* are short, broad at the base, and obtusely pointed; they seem rather to be produced from the body of the spine than implanted; they are opposite to each other, and in this respect differ from those of *P. alternidentatus*, in which the denticles alternate; in the latter also the denticles are much wider apart, the spaces between them being quite double the breadth of the base of the tooth.

An ichthyodorulite from the Linton coal-beds of America is described by Prof. J. S. Newberry in the Palæontological part of the 'Geological Survey of Ohio,' p. 56, pl. lix. fig. 7. It is somewhat similar, judging from the figure, to *P. alatus*. It is more slender; the teeth are more numerous, acute, and recurved; it is also straight and round. *P. alatus* is slightly curved, and the teeth are blunt. The American specimen is named by Dr. Newberry *Orthacanthus gracilis*.

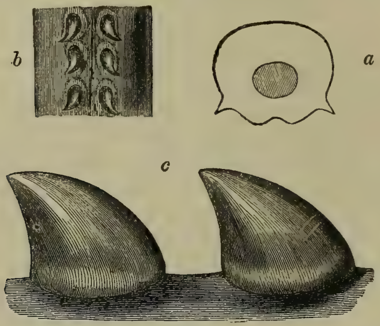
9. Pleuracanthus cylindricus. Fig. 8.

Orthacanthus cylindricus, Agass. Poiss. Foss. vol. iii. pl. 45. figs. 7, 8, 9.

Prof. Agassiz gives a figure of this species along with the name, but does not describe it. A reference is made to the genus in the third volume of the descriptive text, p. 330, as a straight spine, of circular form, with two rows of sharp teeth, the specimen being from the Coal-formation near Manchester.

The length of the spine in a perfect state and full-grown is from 16 to 18 inches. The one I have before me is 16 inches in length. Its greatest diameter, 2 inches from the basal extremity, is ·7 of an inch. From this maximum thickness it tapers gradually and persistently towards the apex, which ends in a sharp point. The spine is circular in form throughout its entire length. There is a round cavity extending from the base to about two inches from the point. Where the thickness of the spine is greatest the cavity occupies one third the diameter, and slightly approaches towards the anterior surface; thence the cavity gradually contracts to a point towards the apex. In the opposite direction the cavity is terminal, the orifice becomes rapidly extended, its walls thin out, and end in a sharp edge at its basal extremity. One inch and a half appears to have been imbedded, the remainder exposed. The external surface is covered with well-marked fine longitudinal striations, which become finer or altogether disappear near the point. On the posterior face there is a double row of obtusely pointed denticles two tenths

Fig. 8.—*Pleuracanthus cylindricus*, Davis.



a. Section of spine. *b*. Portion of posterior surface, showing denticles. *c*. Denticles, enlarged.

of an inch apart, except near the apex (where the space between them is much reduced), slightly curved towards the base. They extend from the point downwards $7\frac{1}{2}$ inches, and increase somewhat irregularly in size with the diameter of the spine or towards the base. The denticles are firmly implanted, round near their base, but contract and form a cone elongated transversely to the longitudinal axis of the spine; so that whilst the points are towards the base, they are also turned decidedly away from the centre of the spine (fig. 8 *b*). In the specimen figured by M. Agassiz*, a median ridge is represented along the posterior face, between the two rows of denticles, and continuing the whole length of the spine. In the specimens I have examined this does not occur: there is sometimes a level surface between the denticles; but more frequently there is a very decidedly hollow groove, which rarely, however, extends far beyond the termination of the denticles.

A section of another spine is represented in fig. 8 *a*, in which the denticles are very widely separated. It is of the same species as the specimen described above; and all the intermediate stages may be traced. In this instance the spine is of the same diameter as the one represented in fig. 8 *b*, whilst the denticles are four tenths of an inch apart, or double the distance. There is also in this example a most decided groove, equidistant between the rows of denticles, and quite one tenth of an inch across.

Locality. Not uncommon in the Coal-measures.

I am indebted to Mr. John Ward for placing at my disposal the beautiful specimens from which the above descriptions have been principally derived. They are from the ironstone shale at Fenton, in Staffordshire. They are much larger and in better preservation than any I have seen from the Yorkshire Coal-field.

* *Op. cit.*

Dr. Goldfuss, in 1847, described and figured *Orthacanthus Dechenii**, found in Coal-measure sandstones at Ruppersdorf, in Bohemia. The whole remains of a fossil fish were found, with the spine still attached to the back part of the head. The fish probably measured 18 inches, and the spine 4·8 inches. The spine is described as "a single, straight, plain, circular, bodkin- or spike-shaped spine, bearing on the posterior surface a row of barbs or denticles slightly distant, alternately right and left of a somewhat elevated median ridge." An enlarged figure of the spine is also given. The distinct median keel, together with the alternate and widely separated denticles, appear to distinguish this spine sufficiently from any other species since described. Its nearest relative is *O. cylindricus* of Agassiz, with which it agrees in being straight, circular, and tapering to a point. *O. cylindricus*, however, has no median keel; and its denticles are close and, for the most part, opposite.

Orthacanthus bohemicus, Fritsch, from Kounova, Bohemia, appears in most respects to be closely related, if not identical with, *P. cylindricus*. It is straight, and finely striated longitudinally. The two rows of denticles are rather closely approximated, and appear to be separated by a median groove.

The three species *P. robustus*, *P. alternidentatus*, and *P. alatus* are extremely interesting, because they serve to bring together into one genus the *Pleuracanthus* and *Orthacanthus* of M. Agassiz. They form intermediate links between the two; the lateral teeth of *Pleuracanthus lævissimus* give place in these species to others, which, though not so widely placed as in *P. lævissimus*, are still very wide apart; the posterior surface enclosed by the two rows of teeth occupies fully one third the circumference; and in this respect they differ equally from the *Orthacanthus cylindricus* figured by M. Agassiz, in which the two rows of denticles are very close together.

Orthacanthus is a circular spine. Not only does this apply to *O. cylindricus*, but to other species which have since been described. *Pleuracanthus* is depressed, forming an oval section. In the species under consideration a triangular form is assumed, caused by the rows of denticles projecting beyond the basal line at its junction with the sides; this is especially the case in *P. alatus*. It has already been mentioned that the specimens of *P.* (*Orthacanthus*, Ag.) *cylindricus* vary much with respect to the position of the posterior denticles; in the type specimens they are quite near together, whilst others, similar in all else, have the rows of teeth placed wide apart. In the example figured (fig. 8 *a*) the denticles are almost as widely separated as in *P. robustus* or *P. alatus*. Taking all these circumstances together, we are driven to the conclusion that there is no generic difference between *Pleuracanthus* and *Orthacanthus*. When Prof. Agassiz described the two genera, only the extreme forms were known; and they appeared sufficiently distinct to warrant their generic separation. During later years many other intermediate forms have been found; and, as was suggested by Sir P. Egerton, the approxi-

* Beiträge zur vorweltlichen Fauna des Steinkohlengebirges (Bonn, 1847), plate 5. figs. 9–11.

mation of the rows of denticles is now proved not to be a feature of such importance as to render a distinct genus necessary; indeed the frequent occurrence of the denticles of *P. cylindricus* widely separated renders this feature of little value. Taken in conjunction with the fact that nearly all the species of *Orthacanthus* described since *O. cylindricus* have been more or less curved, there can be no reason why the genus should not merge in *Pleuracanthus*.

10. PLEURACANTHUS WARDI, sp. nov. Pl. XII. fig. 6.

Imperfect spine, 6 inches long, base and point wanting; broadest part ·5 inch, and the opposite end ·3 inch in diameter. It is curved backwards. The anterior surface is semicircular in section, and covered with very fine longitudinal striæ. The sides are produced somewhat squarely; posterior portion, from the median lateral angle to the point of insertion of the denticles, is depressed, as in fig. 9.

Fig. 9.—*Pleuracanthus Wardi*, Davis.

Section of spine, nat. size.

There are two rows of denticles, extending along 4 inches of the posterior face of the spine in this specimen. In a perfect example the extent of denticulated surface would considerably exceed this length. The rows of teeth are about one tenth of an inch apart, and are separated by a median groove; they are obtusely pointed; the intervening spaces are connected together so as to form a continuous longitudinal ridge, produced from the surface of the spine, rather than a series of separate teeth. The internal cavity is large in proportion to the size of the spine.

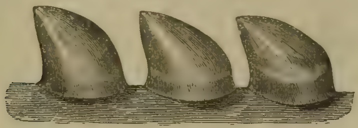
This species is distinguished from *P. cylindricus*, the species to which it is most closely allied in form and characteristics, by its decidedly curved form, by the arrangement of the denticular lines so as to form a continuous ridge with slight obtuse projections, and by the narrower space constituting a simple groove between them. I have much pleasure in employing the name of Mr. Ward, of Longton, in order to distinguish this spine specifically. Like most workers in fossil ichthyology, I have been much indebted on many occasions to his uniform kindness and willingness to render assistance, either by his extensive knowledge or the ample contents of his cabinets.

Locality. New Ironstone (Ragmine), Fenton, Staffordshire.

11. PLEURACANTHUS DENTICULATUS, sp. nov. Pl. XII. fig. 7.

Spine. Length 2·2 inches, diameter ·2 of an inch; basal end not perfect. From the base it becomes gradually smaller, and ends in a fine point. It is slightly curved dorsally. The anterior and lateral surfaces are round and smooth; the posterior is depressed, one tenth of an inch across at the base, contracting to a small groove towards the apex; the angles formed by the contact of the posterior and

Fig. 10.—*Pleuracanthus denticulatus*, Davis.



Denticles of the spine, enlarged.

lateral faces are armed with a series of closely set denticles (fig. 10), which are small, comparatively broad at base, contracting suddenly, then forming a carinated apex, pointed at the extremity towards the base of the spine. There are 20 denticles on each side in the space of an inch; and in the specimen figured there are 45 on each side. A circular cavity (which appears, as usual, to be terminal) extends towards the point; it is large in diameter in proportion to the spine.

Locality. Better-bed Coal, Clifton, near Halifax.

Several specimens which have been obtained from the Cannel Coal at Tingley may probably be referred to this genus. They present some points of difference; but these may probably be accounted for by the relative position of the two stratigraphically, the Cannel Coal being several hundred feet higher in the Coal-measure series than the Bone-bed. The Tingley spines are slightly compressed laterally; the anterior and lateral faces are striated near the basal extremity; the posterior denticles are small and much resemble those of the Bone-bed specimens; the base is better exposed, its walls are rather thin, and the internal cavity is large; the spines expand towards the base. A perfect example will be about 3·5 inches in length.

P. denticulatus appears to be most nearly associated with *P. Wardi*, and with a spine described by Dr. Newberry (in the Palæontological volume of the 'Survey of Ohio,' vol. i. p. 332, pl. lix. fig. 4) as *Orthacanthus arcuatus*. The latter is described as finely striated longitudinally on the anterior surface—the posterior surface occupying one third the circumference, and having a low ridge along the median line. The denticles extending along the latero-posterior angles are much closer together and more numerous, and from the figure appear to be quite different in character from those in my specimen. In all these particulars the two species are clearly divergent; in other respects they are similar; in curvature and general form they are evidently very closely related.

P. denticulatus is easily distinguished from *P. Wardi* by the large size of the latter, the peculiar squareness of its lateral faces, and its obtuse teeth connected together by intermediate ridges. In these respects they differ essentially from each other.

EXPLANATION OF PLATE XII.

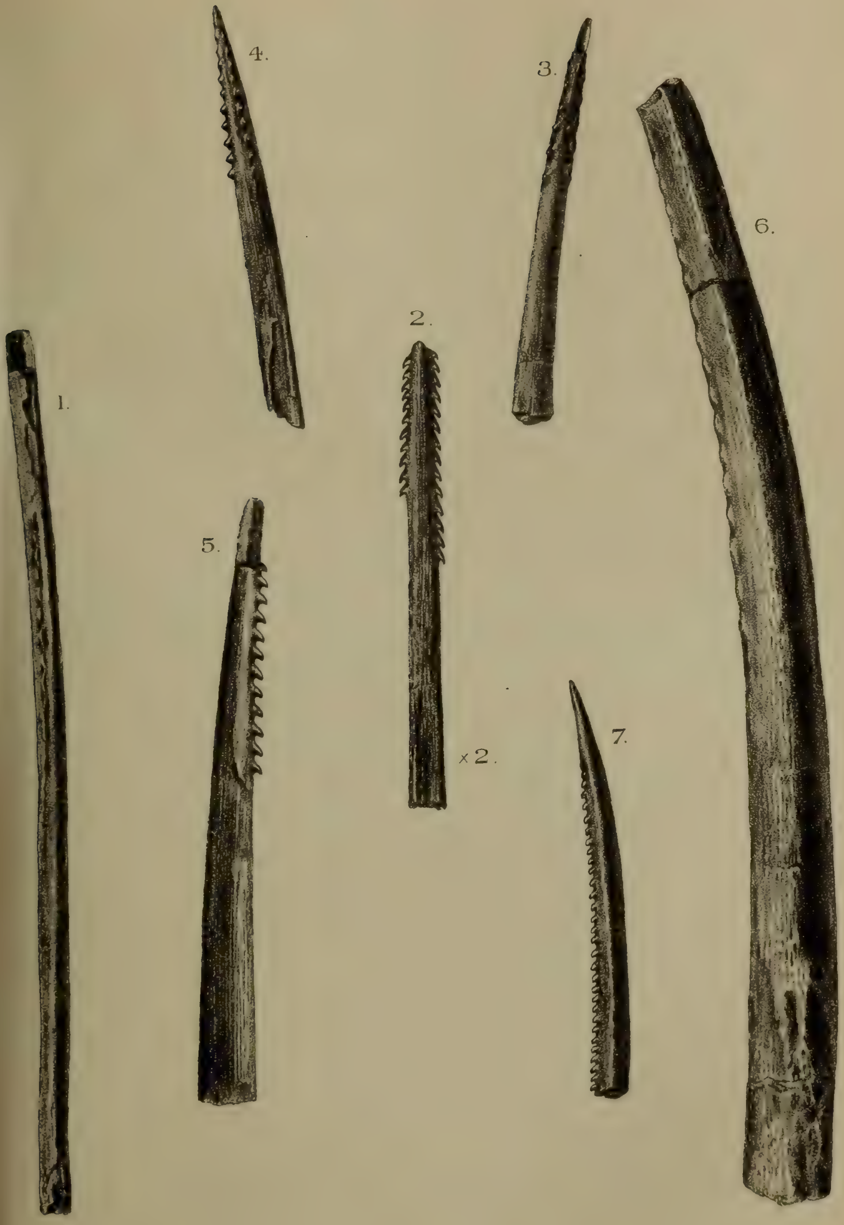
Fig. 1. Spine of *Pleuracanthus tenuis*, Davis, nat. size.
2. Spine of *Pleuracanthus pulchellus*, Davis, twice nat. size.
3. Spine of *Pleuracanthus alternidentatus*, Davis, nat. size.
4. Spine of *Pleuracanthus alatus*, Davis, nat. size.
5. Spine of *Pleuracanthus robustus*, Davis, nat. size.
6. Spine of *Pleuracanthus Wardi*, Davis, nat. size.
7. Spine of *Pleuracanthus denticulatus*, Davis, nat. size.

Discussion.

The President stated that in the southern division of Yorkshire fish-remains are much more common than is usually supposed.

Dr. Duncan remarked upon the variability of spines in fishes. He welcomed the reduction in the number of genera, but was not prepared to accept Mr. Davis's views on the affinities of these fish, especially in the absence of all Teleosteans from the Secondary formations.

The Author stated that many tons of fossil fish-remains must have been destroyed before the interest of the coal band was discovered. In reply to Dr. Duncan, he deprecated the acceptance of negative evidence as to the absence of Teleostean forms in Mesozoic times. He argued that both *Cœlacanthus* and *Pleuracanthus* were probably freshwater fishes, the former possessed of an air-bladder.



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SPINES OF PLEURACANTHUS.

24. *The* Precarboniferous Rocks *of* Charnwood Forest.—Part III. Conclusion. By the Rev. E. Hill, M.A., F.G.S., and Professor T. G. Bonney, M.A., F.R.S., Sec. G.S. (Read May 26, 1880.)

Contents.

In our former communications on this region we gave a general description of the northern district. Though some points were worked ont in detail, yet less time was devoted to this than to the more accessible districts, and several difficulties remained, on which we hoped that renewed work and wider experience would throw some light. Accordingly, during the last two years we have repeatedly visited the neighbourhood, and added largely to our collection of rocks and slides *; the present paper contains the results of these studies, which we venture to hope will not be without interest.

(1) *The Northern District.*

In our brief notice of the beds in the Blackbrook and Charley region, as we had paid no minute attention to them, we followed previous writers in calling some of them quartzites. As will appear from the descriptions below, no rock here can properly be called a quartzite; and we propose to denote this important group, apparently the lowest visible among the Charnwood beds, simply as the Blackbrook series. The normal rock is a pale-greenish sandy-looking rock, commonly much stained with ferrite from the Trias, more or less finely banded, and somewhat cleaved. It is best seen near the Blackbrook toll-gate, on the Ashby and Loughborough road, and here is of a pale greenish grey colour, with reddish stains, somewhat compact and decidedly like a quartzite. Under the microscope it exhibits a clear matrix full of very small microliths (belonites &c.) of a very pale green colour, with irregularly disseminated subangular grains of quartz, and some felspar, now and then stained with ferrite. The microliths are probably a pale fibrous variety of hornblende. With crossed Nicols many parts of the slide show a cryptocrystalline structure, resembling that of a devitrified rhyolite, distinct fragments of which rock appear to be present. From the structure we should suspect that the rock originally was largely composed of a pumiceous dust. The rock by Charley church, which has a general resemblance to the above, and is probably on nearly the same horizon, strongly confirms this view. It is composed chiefly of small fragments, apparently rather angular, but looking as if much compressed, which very closely resemble bits of a rather decomposed

* More than 60 slides have been prepared, all by Mr. F. G. Cuttell, making the total number examined from Charnwood about 150.

glassy trachyte, indications of a fluidal structure being still discernible. Among these (besides the above microliths) occur very angular fragments of quartz and a few of felspar crystals.

At Upper Blackbrook, on a ridge, are beds containing plenty of visible quartz grains, and small fragments of a decomposed, whitish, very compact felsite. On Ives Head, and east of Finney Hill are coarse grits, the grains being principally decomposed felspar or felsite, as if waterworn volcanic material. Some beds, as on the west side of the bed of the old Reservoir, are of finer material, compact flinty slate. A greenish mottled variety occurs in the garden of the farm-house by the isolated outcrop near Charley Wood. It is an ashy grit, seen, under the microscope, to consist of rather rounded grains of felspar with some quartz, and numerous fragments the exact nature of which it is hard to determine; but some certainly seem to be trachytic lapilli, and the whole is not improbably detritus from a trachytic volcano. One of the quartz grains contains a relatively large irregular enclosure which is almost certainly a devitrified glass.

We do not, with our present knowledge, feel in a position to correlate all the outcrops. The series forms a well-marked base to the Charnwood rocks; and the similarity of outcrops on the same strike seems to show that there is little disturbance by cross faults. On the other hand we have more than once suspected some repetition of beds by strike-faults, particularly at Blackbrook. There are arguments both for and against this view.

The beds in this northern region on the east side of the anticlinal have hitherto been supposed to differ entirely from this Blackbrook series. This view we accepted in our former notices. But when we came to examine them more minutely, it appeared that with some differences they had also many common characters. At Short Cliff and some other points green slaty rocks are found closely agreeing with some of the Upper-Blackbrook beds. At the Whittle-Hill quarry and to the west of it are whitish ashy-looking fine grits or gritty slates, whose materials recall the white decomposed felsitic fragments of Upper Blackbrook. The rock of Moorley Hill, where two large quarries are opened, is externally very different; yet, under the microscope, even this appears to have affinities with the rest. Here are dull greenish banded grits, some beds being very fine. The microscope shows the coarser rock to be composed of angular and subangular fragments of quartz, felspar (both orthoclase and plagioclase), with rock-fragments, some appearing to be trachytic, and one showing very distinct traces of fluidal structure. There is iron peroxide, some decomposed ilmenite, and a good amount of viridite; and the felspathic constituents are much decomposed. The materials have probably been arranged by water.

An outcrop about half a mile west of this, seemingly of the lowest beds on the east side of the anticlinal (a quarter of a mile south of the east end of Whitehorse Wood), shows soft ashy grits and fine slaty rock, some of the latter being very like some Blackbrook varieties, while the other is akin to Moorley Hill. Microscopically, the green rock shows the usual constituents, with some signs of decomposition, a larger proportion of viridite, including some chlorite. The materials are probably waterworn.

There is rock in the spinney by the New-Cliff quarry which is externally different from most of the Blackbrook series. It has, however, something in common with the Ives-Head beds. This is a coarse greenish-grey grit, of well-rounded grains. Microscopically, even this has a general resemblance to the specimen from Moorley Hill, except that the greater part of the green mineral is doubly refracting. In both, the felspars with their included microliths and general structure recall those in many modern trachytes.

(2) *Additional Correlations.*

On the west side of the anticlinal the Blackbrook series appears everywhere to be overlain by the coarse ashes of the Monastery, Hanging Stones, &c., the agglomerates of the High-Towers region, and the rocks of Sharpley. If, then, we are right in supposing that the lowest beds on either side of the anticlinal belong approximately to the same series (and the throw of the strike-faults is much less than was formerly supposed), the equivalents of the coarse agglomeratic rocks of the western side ought to be found above the beds already described on the eastern. Bearing in mind the possibilities of change in aspect, we minutely reexamined all the latter district, with the following result:—The soft ashes and pale green flinty slate of Whittle Hill have obvious affinities with the Blackbrook type. But in a spinney due north of the quarry, at no great distance, we found rock clearly *in situ*, not only of an entirely different type, but so closely resembling the Monastery coarse-ash beds, that without the labels our hand-specimens could not be distinguished from some of them. The microscopical evidence agrees with this. There are the usual constituents, a good deal decomposed, with much hornblende giving a more or less schistose structure, and but little quartz. The rock-fragments much resemble devitrified rhyolites; and in parts of the slide the fragmental structure becomes almost obliterated, while in others it is very distinct.

For this correlation there is additional evidence. Above the coarse ashes of the Monastery and Hanging Stones are vast piles of agglomerates. Here, on the eastern side, no such agglomerates occur, so far at least as we know; but we do find at more than one point beds of a dark-green grit, which have no small resemblance to the matrix of some of the agglomeratic beds. Also a thick grit bed on the Buck Hills * has much likeness to a bed on the High-Towers ridge; and though most of the beds hereabouts are banded slates which have no obvious equivalents across the anticlinal, yet it may be noticed that there are indications of stratified

* The coarser rock of the Buck Hills contains a considerable amount of quartz; and the microscope shows many lapilli, one or two exhibiting acicular microliths of felspar, as well as included crystals of the same mineral.

beds at several points near the Monastery, and doubtless those great agglomerates are extremely local and exceptional formations.

We showed, in Part I., that the Monastery coarse-ash beds belong to a horizon which can be traced down the whole western side of the anticlinal as far as Benscliff Wood. Distant from them about a mile, measured across the strikes, we meet at several points (Markfield, Ulverscroft mill, &c.) with agglomerates containing slate which can be traced through Bradgate across the anticlinal to the wood of Blores Hill. We have since traced the Markfield beds (Altar-stones) some distance further to the north-west, and have been struck by their strong likeness to some of the beds at Abbot's Oak (Green Hill), which appeær to overlie by a very short interval the slate agglomerate on High Towers. We have also discovered an agglomerate identical with the Blores-Hill mass in the grounds north-east of Roecliffe Hall. Its strike points to Woodhouse-Eaves Mill, where, also, are beds with fragments of slate. No equivalents can be identified on the continuation of this strike in the grounds of the (Woodhouse) Hanging Rocks; but there is probably some slight bending or faulting; for beyond, at three different outcrops in the Outwoods, are agglomeratic rocks with large fragments of slate, to all appearance belonging to the same horizon *.

We have thus traced the horizon of the great slate agglomerates round three fourths of the circumference of the Forest, from Loughborough Lane in a circuit about to High Towers. As we mentioned above, the coarse-ash beds, whenever found, occur at a distance of about a mile from this horizon. Now the distance from the coarse ash on the Whittle Hills to the slate agglomerates in the Outwoods is almost exactly a mile. Thus the evidence for the identity of the coarse ash above Whittle Hill with that round the Monastery is as strong as the nature of the case admits.

It follows that our estimate of the throw of the anticlinal fault (given in Part II.) must be considerably reduced. The horizon of the slate agglomerates, judging by their position at Roecliffe Hall, must also be much nearer that of the grit and pebble beds than we had previously supposed.

The beds on Longcliff appear by their strikes to underlie those on the Whittle Hills. Yet they have, as we said, no resemblance to the Blackbrook series. Their affinities are rather with those of a much higher horizon. In one or two places fragments of the pinkish felsite were distinctly seen with the eye. Several slides have been examined. Quartz grains are present, similar to those of the Sharpley-Peldar district, and broken felspar crystals also with similar microlithic inclusions †, and numerous lapilli, mostly of the usual rhyolitic type; epidote is present, with much chlorite, viridite, and the usual fibrous hornblendic mineral. On the whole these Longcliff beds have much in common with the finer portions of the beds of the north-western district already described. There is also among them

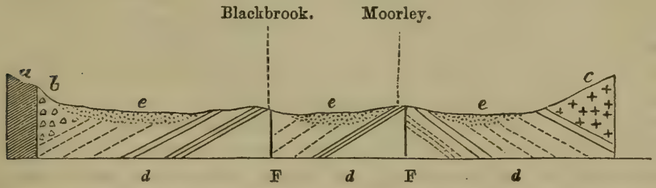
* We may notice, in passing, that the agglomerates of this horizon contain fragments which we took originally to be purple slate, but now recognize to be purple rhyolite.

† See p. 343.

an agglomerate with slate fragments; and slate fragments belong in general only to the higher portions of the Charnwood series. We are inclined, therefore, to think them dropped down here by some faulting. A chain of greenstone intrusions (two of which are new discoveries) extends from New Cliff, over Long Cliff, to the Buck Hills, and may possibly have some relation to the position of the fault, if such exists.

The annexed section, which is only diagrammatic, may serve to render clearer our idea of the general relation of the beds on either side of the anticlinal at the northern end of the Forest. It is drawn in accordance with Prof. Bonney's view—that the Blackbrook-toll-gate beds are about the lowest of all, and that a fault parallel with the anticlinal fault has a larger throw than it.

Fig. 1.—*Diagrammatic Section (on a line curving to N.) to express the probable relation of the beds in the northern part of Charnwood Forest.*



a. Sharpley Rock. *b.* Coarse Agglomerate. *c.* Fine Volcanic series.
d. Blackbrook series, slaty in upper part. *e.* Trias.

(3) *District of Sharpley, Ratchet Hill, and Peldar Tor.*

We gave in Part I.* a general description of these beds, stating that, after careful comparison of the Sharpley rock, that of the basement beds of Ratchet Hill, and the rock of Peldar Tor, we consider them the equivalents one of another. We have subsequently examined more minutely the whole district, with the following results:— In the first place, we have detected the characteristic rock which forms the ridges of High Sharpley, at the base of Peldar Tor itself (near to Spring-Hill Farm), in two little spinneys to the north of this, and near another farm in the direction of Kite Hill. We have also traced this rock to the north of High Sharpley, and found that at last it is either split up by small slaty bands, or contains lenticular fragments of slate, and passes at one place into a purplish agglomerate†. There is then a very considerable mass of rock of the type found at High Sharpley, and it clearly underlies the beds visible in the main part of Ratchet Hill and Peldar Tor; further, among the lowest beds of the former, together with a green rock, like that of Bardon Hill, is some of the Sharpley type. Microscopic examination also showed that the difference between these two rocks was more apparent than real.

It results, then, that the Ratchet-Hill and Peldar-Tor rocks are

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 777.
† On the map, just under the *e* in "Swanymote."

about on the same horizon; and though the former are much less uniform than the latter, containing well-marked agglomeratic beds, yet parts may be found even here very closely corresponding with the typical Peldar-Tor rock. On that hill fragments seem to have become rare and small; but the crystals of quartz and felspar are rather larger.

This rock of High Sharpley is one presenting several difficulties. Its ground-mass is of a purplish grey colour, and is compact, much like a felsite, containing numerous crystals (often fairly perfect) of quartz and felspar, sometimes as much as $\frac{1}{3}$ inch in diameter, but generally rather less. It has a distinct though imperfect cleavage, the surfaces being wavy (doubtless owing to the resistance of the included minerals). These surfaces have a very faint satiny lustre, giving the rock at first sight a slightly schistose aspect. Cleaved felsites do, indeed, sometimes look rather schistose; but the latter structure is usually very local; while the thickness and extent of this Sharpley rock is considerable, and its character uniform*. Further, there is in its aspect something hardly to be described in words, which to the practised eye suggests a doubt of its igneous origin. Here and there we note a very faint indication of a fragmental structure; and at the western end of the southern ridge, and again about halfway along it, the rock becomes unquestionably clastic, containing in an ashy matrix fragments of a purplish porphyritic felsite, which is itself extremely like the typical Sharpley rock †.

Eight microscopic slides have been prepared from different parts of the ridges of High Sharpley, and four from other outcrops in the vicinity. The ground-mass of these is often, at first sight, remarkably like that of an acid lava, as it consists of a transparent base, crowded with microliths of opacite and ferrite, with epidote and (?) sericite, generally rather irregular in form. The first and second are so arranged as to give the slide a more or less granular structure, which in some cases is well defined, and then the ground-mass is more translucent. In one or two of the slides a vague indication of fragmental structure can be discerned. In this ground-mass are scattered crystalline grains of quartz and felspar (small and large), of iron peroxide, and of epidote and viridite replacing some other mineral. With crossed Nicols the rather granular aspect of the slide nearly or quite disappears, and the field resembles a glass crowded with inumerable microliths, mostly, if not all, felspar, often rather

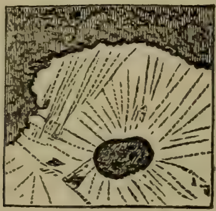
* We have received from a friend a partial analysis of this rock, which may give a general idea of its composition:—

SiO_2	$=68 \cdot 05$
Al_2O_3, Fe_2O_3	$26 \cdot 23$
CaO	$1 \cdot 28$
MgO	$1 \cdot 10$
Alkalies &c.	$3 \cdot 34$
	$100 \cdot 00$

† The same rock is found on Ratchet Hill and elsewhere: see p. 344.

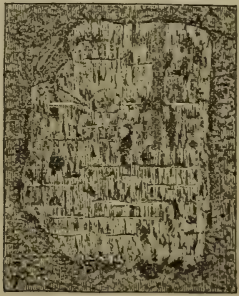
wavy and indefinite in outline, bearing a general resemblance to a cryptocrystalline structure common in devitrified rhyolites. On rotating the stage other microliths appear in the dark parts; and it is doubtful whether any glass really remains. Minute quartz grains, so far as they can be recognized, are not numerous. Most of those present are from $\frac{1}{8}$ to $\frac{1}{4}$ inch. In outline they vary, being sometimes rounded or subangular, sometimes showing crystalline angles; they are often traversed by cracks; occasionally they include a little of the ground-mass and specks of viridite, but usually are fairly clear, though here and there are a good many enclosures, some being opacite, but many almost colourless, like minute cavities (fig. 2). The

Fig. 2.—*Portion of broken Quartz Crystal, with Inclusions of Matrix minute Cavities* (?), *&c. High Sharpley.* (Enlarged.)



felspars are rather decomposed and stained with ferrite; but orthoclase and a plagioclase, probably oligoclase, can be recognized. Both include numerous microliths of epidote, viridite, and perhaps another

Fig. 3.—*Felspar Crystal with Inclusions resembling Brown Glass, &c., High Sharpley.* (Enlarged.)



rather similar mineral, together with a substance much resembling a brown glass *; these often lie in the planes of cleavage (fig. 3). These felspars are frequently in perfect crystals, but sometimes appear

* The general aspect of these felspars is remarkably like those in many trachytes.

broken. The large grains of epidote are obviously of secondary formation; from their octagonal outline and angles we may, in two cases, safely assert the original mineral to have been augite; viridite appears, both associated with it and alone, probably also replacing a kindred mineral.

Slides cut from the rock at the base of Peldar Tor, from the Sharpley-like rock in the Bardon-Hill pit, and from the outcrops mentioned above have been carefully studied: their differences from the above are merely varietal; and the green rock at the base of Ratchet Hill, though containing a little more viridite, is in all essential points identical.

The question, then, we have to answer is: Are these rocks lavas? and if not, how is their porphyritic structure to be explained? Certainly they are not unlike lavas; the cryptocrystalline ground-mass, the included crystals, would not ill agree with a devitrified rhyolite such as we can examine in the Wrekin district, or between Caernarvon and Bangor. Still, on closely studying the ground-mass of these Sharpley rocks, we note various minute points of difference, such as an indefiniteness of structure, a suggestion here and there of fragments, which seem to separate them from every undoubtedly igneous rock which we have studied. The persistent schistose character of the rocks over so large an area is also most difficult to explain on that supposition. So also is the gradual passage of the undoubtedly fragmental bands (in the southern ridge) into the normal rock. Were the latter a lava, the line of demarcation between it and the ash-bands should be a definite one, and be detected without much difficulty, as the rock-surfaces exposed are favourable to examination. After repeated study in the field and with the microscope, and comparisons with numerous type specimens, we cannot alter our original opinion that these rocks of High Sharpley are not lavas.

We are then called upon to explain their porphyritic structure. The quartz and felspar grains closely resemble those occurring in many other Charnwood rocks which undoubtedly are of clastic origin; they also resemble them in having clear, sharp boundaries, even when broken. There is not that indefiniteness of outline and appearance of melting away (as it were) into the surrounding ground-mass which commonly characterizes crystals (especially of felspar) when developed *in situ*, in schists; the structure of the ground-mass also does not resemble that of schists; nor do the rocks themselves in this part of Charnwood Forest suggest very extensive metamorphism. The idea, then, of a development *in situ*, as in the case of many crystals of garnet, dipyr, hornblende, chiastolite, &c., seems inadmissible. But if so, the aspect of the included minerals, and the general structure of the rock, can only be explained on the supposition that it is a tuff. The bands already mentioned, which are undoubtedly fragmental, are certainly of volcanic origin. The structure of the fragments in them and in the agglomerates of Ratchet Hill and elsewhere is almost identical with the ground-mass of these Sharpley rocks. Still, if the latter be of fragmental origin, it may fairly be asked, What has become of the lapilli? why are they not as usual more or less clearly defined in the slide? To this we may reply, that here and there we do meet with faint indications of these; that in two intercalated bands separated by no clear line of division they unquestionably occur; that a similar tendency to disappear may be occasionally noticed in slides from rocks in other parts of Charnwood which are of undoubtedly clastic origin; and, lastly, that in some comparatively modern tuffs a similar obliteration of the fragments may be witnessed *.

We suppose, then, that this rock of High Sharpley and elsewhere was once a rather fine uniform rhyolitic tuff, consisting of lapilli and volcanic dust, mixed with quartz and felspar crystals, which perhaps no long time after deposition was exposed to the action of percolating water or vapour, and, as it were, partly rotted †, but without destroying the included felspar crystals. It was then consolidated, cleaved, and gradually brought to its present condition. The rock of High Sharpley much resembles some of the "porphyroïdes" of the Ardennes, the chief difference being that sericite is much less conspicuously present in the former than in the latter ‡.

We described in Part II. the ordinary rock of Peldar Tor. Since then we have had additional sections prepared. The study of these and our field-work confirm us in the opinion, there expressed, that the rock is of clastic origin. We may, however, remark that the quartz and felspar crystals are in most respects identical with those of Sharpley; and the general character of the ground-mass, especially with crossed Nicols, is the same. As the rock in the main mass of Ratchet Hill § is indubitably pyroclastic, and is now proved by superposition on the typical Sharpley rock to be equivalent to that of Peldar Tor, our view as to the nature of the latter and of Sharpley receives additional confirmation §.

The rock near Copt-Oak church (noticed vol. xxxiii. p. 771) has

* As, for example, in a white tuff from Monte Venda, Euganean Hills, of the British-Museum collection, for a sight of which we are indebted to Mr. T. Davies, F.G.S. Since writing the above, we find a somewhat similar case described by Prof. Geikie, "Volcanic rocks of Firth of Forth," Tr. R. S. Edin. vol. xxix. p. 474.

† Lapilli are very commonly outlined by a black margin, which probably largely owes its colour to ferric oxides. The passage of water or vapour through the mass would decompose the iron oxide (forming carbonates, &c.), and thus obscure the structure.

‡ I am indebted to Prof. Renard for specimens of porphyroïdes from Laifour and Mairus (described in the well-known memoir 'Les Roches Plut. de la Belgique' &c.). Early in the present year, I fortunately had the opportunity of showing him my collection of rocks and slides from Charnwood. He informed me that the resemblance of the Sharpley, Peldar, and Bardon-Hill rocks to those of the Ardennes was most remarkable, and expressed a distinct opinion that none of them were lavas. In the above memoir it is suggested that the quartz and felspar crystals have been developed *in situ*; but after examination of my collection, he stated that, in the case of Charnwood, he thought the view mentioned above worthy of serious consideration.—T. G. B.

§ A careful search over the rocky ridge will show here and there near the base a tendency to recur to the Sharpley type, and higher up bands closely approaching the Peldar-Tor type.

some resemblance to members of the above series. We had feared that its decomposed condition would unfit it for microscopic examination; but Mr. Cuttell has succeeded in preparing us a good slide from a specimen rather of the Sharpley type. Except for the entire or almost entire absence of quartz, and the larger amount of viridite and ferrite present, it is remarkably like that rock. The ground-mass is similar; the included felspar crystals, often sharp-edged as though broken, are in all respects identical. Part of the green mineral is rather fibrous, dichroic, and probably a chlorite. The ferrite has infiltrated into cracks. This rock, then, is probably about on the horizon of the Sharpley series.

(4) *Bardon Hill.*

The quarry here has been much enlarged since the date of Part II. A considerable mass of the purple schistose rock in the upper quarry has now been excavated. As already stated, it much resembles that on High Sharpley, except that it has fewer quartz grains. It appears to pass up irregularly into a greenish rock; and at one place there seemed to be a parting of this between two bands of the purplish rock. Its thickness also seemed variable. The dip was not very clearly marked, but appeared to be about 48° N.W., the strike of the cleavage being W. 10° S. This rock seems to end abruptly; as the foreman said, "it dies out at a slither." The approximate N.E. to S.W. strike differs much from that of the "shaly band" in the lower pit, which is W.N.W. to E.S.E. It is, then, very probable that a fault runs near the northern flank of the pit. On reexamination of the "shaly band" we were struck with a resemblance between the less decomposed portions of it, the ashy bands of High Sharpley, and parts of the purplish rock in the upper pit. Microscopic examination has not, however, strengthened the evidence for this resemblance; for our slide of the first appears to consist of broken felspar crystals, often much decomposed, a few grains of quartz, and a large quantity of viridite so arranged as to give a rather schistose aspect to the rock, no part preserving the peculiar cryptocrystalline structure noted in the others. Still, in our slide from the purplish rock in the upper pit, there is a small lenticular band consisting wholly of broken felspars (with epidote); so that the identity is yet possible. If this were the case, and the shaly band an attenuated representative of the Sharpley rock, then that already described * as so curiously like the Peldar-Tor rock would be in its right place, and the typical compact green rock † of the pit would belong to some part of the Peldar-Ratchet

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 781; vol xxxiv. p. 205.

† As this rock, perhaps more than any other of its kind in the Forest, resembles a true felsite, we have had additional slides prepared. We retain, however, our former opinion that it is not an igneous rock. We need only refer to our descriptions given at p. 206, vol. xxxiv., and repeat that our study of all these peculiar rocks in the northern district confirms us in the opinion that they are not only clastic, but also have been tuffs, and that the amount of alteration which they have undergone is not sufficient to account for their porphyritic character.

series. The resemblance of the breccias in the upper part of the hill to those of Cadman has already been noticed.

Be this as it may, the rocks of Bardon Hill, as a whole, have a marked resemblance, especially under the microscope, to the group described in the last section; thus it is very probable that this Sharpley-Cadman series, in an attenuated condition, reappears here on the other side of a synclinal, which most likely is more or less broken by faults.

(5) *Fragments in Agglomerates.*

A few fragments from the agglomerates have already been described in Part II.; but in the hope of throwing light on the structure of the Sharpley rock and obtaining hints for conclusions, ten carefully selected fragments have been subsequently examined microscopically. They are from the following localities:—Ratchet Hill (2), Gunhill (1), High Towers (4), Timberwood Hill (1), near Whitwick school-house (1), Whitwick Parish Quarry (1). The specimens from Ratchet Hill have a minutely cryptocrystalline ground-mass with scattered crystals of quartz, felspar, magnetite and secondary epidote. The first two minerals resemble those in the Sharpley rock; and there is much similarity in the ground-mass. One of the High-Towers specimens (from an agglomerate nearly opposite to the lodge) shows a faintly mottled structure, which is rendered more distinct by a marked difference of colour on applying a selenite plate. Probably it is the remains of a structure similar to those figured by Zirkel in plates vi. and viii. of his "Microscopical Petrography" (U.S. Geol. Explor.). We find also that the mottled pink and green fragments, somewhat like syenites in macroscopic structure, differ but little from the purple fragments. The ground-mass is cryptocrystalline, and in this particular specimen shows fairly distinct traces of a fluidal structure. The others call for no special note. The microliths in the Whitwick School-house fragments (rather decomposed) are more acicular than in the others; that from the Whitwick Quarry (also rather decomposed in parts) exhibits distinctly an irregular fluidal structure. In our former notice (vol. xxxiv. p. 208) we doubted whether two specimens from the last locality were igneous; having in the interval enjoyed many opportunities of studying both the older trachytic rocks and the "hälleflinta" group generally, we have now no hesitation in recognizing all as igneous. The structure then described is analogous to that mentioned above in one of the High-Towers specimens.

These fragments also, allowing for decomposition and the formation of some secondary minerals, present very considerable resemblance to many rhyolitic rocks of much more recent date, such as those of Hungary; it is even possible that an undevitrified base may occasionally remain. Their structures are hardly distinctive enough to throw much light upon correlation. The Gunhill and Whitwick School-house specimens, which differ more from the ordinary type, are most alike; but it is quite possible for all to belong to the same general series. Field evidence inclines us now to regard the Gunhill rocks as representative rather of the Kite-Hill than the Cadman group.

(6) *The Slates.*

The microscopic structure of three varieties of slate was described in Part II. The structure of one of them (from the quarry near Forest Rock Inn) appearing on further investigation to be rather exceptional, we have examined a few more slates in the hope of obtaining some help in correlation. The only one among them which presents any resemblance to it is a specimen from a locality east of Grace-Dieu grounds. The peculiarity of the Forest-Rock-Inn slate is that the slide with ordinary light is unusually clear, resembling a glass in which a number of very minute microliths, of a pale yellowish-green colour*, with some specks of ferrite, are irregularly disseminated, so as to leave occasional clear interspaces; and this base, with crossed Nicols, exhibits a kind of devitrified structure. The other slide has very similar microliths and brown specks, a clear matrix showing a similar structure with crossed Nicols, but more obviously clastic, fragments of felspar crystals being in places distinct. There seems to be some evidence for correlating these two rocks; but, unfortunately, this does not help much, as the position of each in the series is uncertain, and probably both are bounded by faults.

In the Whittle-Hill honestone the matrix seems to be fairly clear, with little earthy matter, but crowded with minute microliths as above, looking as if it were composed of comminuted felspar, in which occur rather larger grains of felspar and quartz. The microliths are a little more wavy in outline than those in the other rocks, and assume, with crossed Nicols, a golden-yellow tint. There are small clusters of ferrite, associated with granules, which are probably garnet. This rock has a slight resemblance to the other two.

The specimen from the quarry west of the School House, Grace Dieu, has also a slight resemblance to the above, but is more crowded with yet smaller microliths, and has a good many specks of ferrite or some pale earthy mineral. A flinty slate from a knoll on the west side of Old-John Hill rather resembles the last. There are occasional distinct felspar fragments and quartz, with grains of epidote, which the microliths may also be.

The slate of Beggar's Nook is distinctly banded; the felspar fragments are rather angular and sometimes long, quartz apparently rare, microliths as before, but the general appearance more earthy. The slate of the summit of Old-John Hill, on the whole, resembles the last. The slate of Groby Quarry, which may be taken as a fair example of the roofing-slates of the Forest, differs much from all the above. It has the usual microliths, with a fairly uniform fragmental structure, consisting of subangular quartz, decomposed felspar, grains of opacite, ferrite, viridite, and mica. The viridite, like the microliths, is no doubt a secondary product; but the mica seems an original constituent. It is generally clear and gives bright colours with crossing Nicols; but occasionally it is interbanded with a pale green variety. Probably a little alteration has taken place.

* Perhaps epidote; some of the darker grains are not unlike menalite.

(7) *Igneous Rocks.*

We have not revisited more than one or two of the localities where these occur since the date of our last paper, and therefore have nothing to add from personal knowledge; but we have detected two new outcrops on the north-eastern side of the Forest—one in a spinney between Whittle and Buck Hills, the other just east of the high road on the crest of Nanpanton. Both are of the northern type (see vol. xxxiv. p. 216), rather compact and decomposed. We could not succeed in hitting off their junctions with the sedimentary rocks; but a more minute search, under favourable circumstances, may yet discover them.

Mr. S. Allport, however, has been fortunate enough to find junctions, exposed by further quarrying, between the hornblendic granite and the so-called Brazil-wood gneiss, showing that the former, as we predicted, is intrusive in the latter *. He justly objects to applying to this the name "gneiss," though we are not persuaded that the term which he proposes for it, "micaceous schist," is much better. He has also been able to prove that this rock is only a member of the Forest series exceptionally altered by "contact metamorphism" †. Mr. W. J. Harrison had previously discovered small garnets in the "gneiss" ‡. The same gentleman has kindly forwarded to us specimens of a very coarse variety of the "syenite" from a pit near Stony Stanton, on the road to Sapcote. This might almost be called a hornblendic granite rich in felspar, some of the crystals of the latter mineral being nearly an inch long.

Conclusion.

As the result of the above investigations, we venture to extend, with some modifications, the correlations proposed in our first paper (vol. xxxiii. p. 784), as follows:—The Charnwood-Forest rocks seem to fall naturally into three great groups, which, however, are not separated by any very sharp lines of demarcation. The lowest is the Blackbrook series. The middle group has for its base the coarse ash-beds of the Monastery, the Hanging Stones, Timberwood Hill, Chitterman Hill, Benscliff, and (east of the anticlinal) the spinney above Whittle Hill. In the north-west region this group contains the immense agglomeratic masses of the High-Towers area; in the north-east the finer volcanic grits of the Buck-Hill district, and probably Longcliff; but here and in the rest banded slates predominate. Rather high up in the group the beds of slate-agglomerate form an horizon which, as above described, can be traced nearly round the Forest district, and might, if thought desirable, be

* Geol. Mag. dec. ii. vol. vi. p. 181.

† The ashy rocks in the Stable Quarry, Bradgate, and at Stewards-Hay Spring (vol. xxxiii. p. 201) are also examples of contact metamorphism. In the first part of our paper the term "schist" was two or three times used where we ought to have said "schistose rock." In the sense in which we think it right to use the former, viz. denoting rocks which are either distinctly "foliated" or have undergone a similar amount of change, there is (apart from the Brazil-wood rock) no schist in the Forest.

‡ Midland Naturalist, vol. ii. p. 77.

used as the base of a subdivision. Above this, in the north-west, appear to come the Sharpley and Peldar rocks, with the agglomerates of Cadman (and their equivalents in Bardon Hill), which are probably succeeded by the finer beds of the quarry near Whitwick School House. Some portion of this upper subdivision may be represented by the Forest-Gate beds in the north-east; and the upper limit of the group further south seems to be marked by the pebble-beds and quartz grits of the (Woodhouse) Hanging Rocks, the Brande, the Stable Quarry (Bradgate), and Steward's-Hay Spring. The highest zone, visible only in the more southern part of the Forest, contains the less-banded workable slates of Swithland and Groby.

The beds are elevated in an elongated dome-shaped anticlinal, of which only one half is visible, and the vertex points to the south-east; so that denudation has exposed the lowest beds at the northern end, and the others lap round them in rudely elliptical zones. These are interrupted by the anticlinal fault or faults, and, at the north-western corner, by many fractures, which greatly perplex the investigator.

Much yet remains to be done in the Forest region; but we are not hopeful that more of importance will be accomplished (unless new quarries are opened) without constant and minute reexamination of the ground, such as is impossible for any but residents in the vicinity. We therefore now take our leave of Charnwood Forest, in the hope that some of the local geologists will continue our task. We are well aware that some at least of our conclusions are founded on imperfect evidence, and we cannot hope to have avoided error; but we may fairly claim to have bestowed upon our work considerable time and pains. We venture therefore to deprecate hasty criticism, and trust that our mistakes may be judged leniently.

Discussion.

Dr. Sorby said that, in preparing his Address, he had found great difficulty in deciding between altered ashes and eruptive rocks. His work had chiefly been among the Westmoreland rocks. He considered this one of the most difficult problems, and was very glad to hear the authors' conclusions.

Mr. Tawney entirely confided in Prof. Bonney's results. With respect to the secondary development of the crystals, having been shown many of the thin slices, by the author's kindness, he thought it was especially clear that the quartzes had been derived, viz. from a rock like a quartz-felsite.

Dr. Hicks expressed his agreement with the view of the authors as to the Sharpley rocks being tuffs. He thought the Charnwood series pre-Cambrian.

The President stated that gold had recently been found in small quantities by Mr. How in the quartz-veins of Peldar Tor.

Rev. E. Hill said the authors were inclined to regard the Charnwood rocks as pre-Cambrian. The occurrence of gold was new to them.

25. *On the* Occurrence *of* Marine Shells *of* Existing Species *at* Different Heights *above the* Present Level *of the* Sea. By J. Gwyn Jeffreys, Esq., LL.D., F.R.S., Treas. G.S. (Read June 9, 1880.)

While engaged in working out for the Zoological Society the Mollusca of the Expeditions which I undertook in 1869 and 1870 in H.M.S. 'Porcupine,' I was much struck by the discovery, at great depths in the North Atlantic, of certain shells in a living state which had been previously known only as Subapennine and South-Italian fossils, and were considered extinct.

To give some idea of the extent to which such changes of sea and land must have taken place within a geologically recent period, I subjoin an extract from my paper on some of the 'Porcupine' Mollusca, which was published in the 'Proceedings' of the Zoological Society for 1879, pages 586 and 587. With reference to *Malletia excisa*, I said, "It will be seen that the last species, as well as many other deep-water shells which have been noticed in the present paper, are Calabrian and Sicilian Tertiary fossils. Besides these species, others of the same kind, and which had been also considered extinct (viz. *Leda* or *Tindaria solida*, Seg., *Nucula glabra*, Ph., and *Malletia dilatata*, Ph.), occurred in the 'Challenger' Expedition. The communication between the North Atlantic and the Mediterranean must have been formerly very different from what it is now, when a barrier or ridge in comparatively shallow water exists outside the Straits of Gibraltar, between Capes Spartel and Trafalgar. It is improbable that deep-sea Mollusca, even in their embryonic state, could have migrated or been transported under such conditions from one sea to another. The south of France and Italy must have experienced a great elevation, and perhaps a succession of them, since the Pliocene period. For instance, the average depth at which *Malletia excisa* has been now found living is 1507$\frac{1}{3}$ fathoms, or 9044 feet, being very nearly five sixths of the height of Mount Etna above the present level of the sea; and to this submarine elevation must be added the height of the Pliocene beds above the sea-level. Professor Seguenza informs me that *M. excisa* occurs in Sicily, as well as in Calabria, at a height of 600 metres, or nearly 2000 feet, and that these fossiliferous beds attain double that height in other parts of the same district; so that the total elevation may be estimated at from 11,000 to 12,000 feet. Mount Etna is 10,874 feet high."

Numerous fossiliferous beds, showing a greater or less amount of oscillation, have been observed throughout the whole world, and especially in the northern hemisphere. In Shetland and Scotland they extend from a depth of 80 fathoms (480 feet) to a height of at least 500 feet above the sea, making together an elevation of nearly 1000 feet. In England and Wales they appear from the level of the sea-shore to Moel Tryfan in Carnarvonshire, at heights of between 1170 and 1350 feet. The last-named deposit is a raised beach; I will give a list of the fossils at the end of this paper. On the Wicklow Hills, in Ireland, the Rev. Maxwell Close is said to have found marine shells at the height of 1300 feet. In Scandinavia, the range of level is from 50 fathoms (300 feet) to 540 feet s.m. =840 feet. In Russia, Murchison and Verneuil noticed sea-shells of arctic species 250 English miles from the White Sea, and 130 feet above its level; and Count von Helmersen has lately stated that such shells occur in Siberia, nearly 500 miles southwards. In Canada, the late Sir William Logan has recorded a raised sea-beach with shells on Montreal Mountain at 460 feet above the Atlantic. In the arctic regions fossiliferous beds are widely distributed, and attain an elevation of from 50 to 1000 feet. The extent of subsidence there is not known. In addition to the above-cited testimony of Professor Seguenza, Professor Judd tells me that in the isle of Ischia he found shells of apparently Mediterranean species at a height of 2000 feet *.

With respect to the climatal nature of these shells, I am not aware that any arctic or peculiarly northern species have been noticed in the raised beaches which fringe the western and southern coasts of England (*e. g.* Barnstaple Bay, and Hope's Nose near Torquay), nor in the north or west of France; but they especially characterize all the other countries and places above mentioned, as well as Sicily, where such northern forms as *Cyprina islandica*, *Mya truncata*, *Saxicava norvegica*, and *Buccinum undatum* are not uncommon as Tertiary fossils, although now absent from the Mediterranean. How is this to be accounted for? The speculative and unscientific notion that species "retreat" in consequence of altered conditions, will not help us to answer this question.

Another question arises as to the permanence or long duration of the oceanic basins, a subject which has been lately treated by my friend and colleague Dr. Carpenter, in his very interesting Lecture at the Royal Institution of Great Britain, and has since been discussed in 'Nature.' As it has been shown that *Malletia excisa* and many other existing species of Mollusca which at present are known to inhabit great depths only, are found in a fossil state at considerable heights above the present level of the sea, so as to show an elevation of from 11,000 to 12,000 feet, or nearly 2000 fathoms, such elevation having taken place at a very late and comparatively recent stage of the Tertiary or Post-Tertiary epoch, and considering that no trace of any organism belonging to even the Miocene formation has been detected in any of the deep-sea explorations (although the rate at which the slight submarine deposit, far from land, is formed by the débris of surface-animals and plants, is known to be exceedingly slow), can we rightly assign to the present oceans that geologically remote antiquity which is claimed for them? Dr. Carpenter says, "The deep-sea soundings of the 'Challenger' have brought out

* See also Lyell's 'Elements of Geology' and 'Principles of Geology' as to the height of Newer Pliocene beds in Sicily.

this remarkable fact, that the ocean-floors present a uniformity of level which corresponds with that of our most level and extensive continental plains." This may be so; the 'Challenger' soundings were necessarily few and far between; but the numerous and close-set soundings lately taken for the new submarine telegraph-cable from Valentia to Newfoundland tell quite a different tale, and serve to show the extreme unevenness of the ocean-floor in the North Atlantic, to say nothing of the depth of 748 (between 1168 and 1260 fathoms) ascertained by the 'Bulldog' soundings, and of 690 (between 1450 and 1230 fathoms) in another part of the same ocean, ascertained by the 'Valorous' soundings. More data would certainly be desirable.

Mr. Murray, one of the 'Challenger' naturalists, and who has especially studied the oceanic deposits, gave at Manchester, in December 1877, two admirable lectures on the physical and biological results of that Expedition, and expressed his belief that the ocean-basins are of "vast antiquity," but that "on the whole they have been areas of subsidence." The word "antiquity" is, of course used relatively to the question of the time occupied in the subsidence, which we have no means of ascertaining or even guessing.

It may be said that Sicily has long been the seat of intense volcanic energy; but has not every other part of the world been in its turn also subject to similar action?

I append a list of the marine organisms which have been found on Moel Tryfan by Mr. Trimmer, Mr. Darbishire, Capt. Drury Lowe, Professor Ramsay, Mr. Etheridge, Mr. Bateson (the proprietor of the Alexandra slate-quarries), and Mr. Mackintosh. The specimens collected by Mr. Trimmer are in the Museum of this Society; and other specimens are in the Museum of Practical Geology. I have examined all the specimens—except some of those included in Mr. Darbishire's list, which I will give in italics.

MOLLUSCA.

Conchifera.

Ostrea edulis, *Linné*.
Pecten opercularis, *L.*
Mytilus edulis, *L.*
M. modiolus, *L.*
Leda pernula, Müller.
Pectunculus glycymeris, L.
Cardium echinatum, *L.*
C. fasciatum, Montagu.
C. edule, *L.*
C. norvegicum, Spengler.
Cyprina islandica, *L.*
Astarte sulcata, *Da Costa*; and var. elliptica.
A. borealis, *Chemnitz.*
A. crenata, Gray ("crebricostata," *Forbes*).
A. compressa, *Mont.*
Venus exoleta, L.
Tapes virgineus, L.

T. geographicus, *Ch.* ("pullastra," *Mont.*).
Tellina balthica, *L.*
T. calcaria, Ch. ("proxima," *Brown*).
Donax vittatus, Da C. ("anatinus," *Lamarck*).
Mactra solida, *L.*; and var. "*elliptica*," Brown.
M. subtruncata, Da C.
Corbula gibba, Olivi ("nucleus," *Lam.*)
Mya truncata, *L.*
Saxicava norvegica, *Sp.*
S. rugosa, *L.*
27 species and 2 varieties.

SOLENOCONCHIA.

Dentalium entalis, *L.*
D. striolatum, *Stimpson* ("abyssorum," *M. Sars*).

GASTROPODA.

Patella vulgata, *L.*
Fissurella græca, *L.* ("reticulata," *Da C.*).
Trochus magus, *L.*
Lacuna divaricata, *Fabricius.*
Littorina obtusata, *L.*
L. rudis, *Maton.*
L. litorea, *L.*
Turritella terebra, *L.*
Natica affinis, Gmelin ("clausa," *Broderip* and *Sowerby*).
Trichotropis borealis, *Brod.* and *Sow.*
Aporrhais pes-pelecani, *L.*
Purpura lapillus, *L.*
Buccinum undatum, *L.*
Murex erinaceus, *L.*
Trophon barvicensis, Johnston.
T. clathratus, *L.*; and var. truncata.
T. latericeus, *Fabr.*
Fusus antiquus, *L.*
F. gracilis, Da C.
Nassa reticulata, *L.*
N. incrassata, Müll.
Pleurotoma nebula, *Mont.*
P. rufa, *Mont.*
P. pyramidalis, *Ström.*
P. turricula, *Mont.*
Cypræa europæa, Mont.
28 species, and 1 variety.

CRUSTACEA.

CIRRIPEDIA.

Balanus Hameri, Ascanius.
B. crenatus, *Bruguière.*

ANNULOSA.

ANNELIDA.

Serpula triquetra, *L.*

PROTOZOA.

SPONGIA.

Cliona, 2 species.
Total 60 species, and 3 varieties.

Eleven of the species of Mollusca in the above list are arctic or northern, viz. *Leda pernula*, *Astarte compressa*, *A. borealis*, *A. crenata*, *Tellina calcaria*, *Saxicava norvegica*, *Natica affinis*, *Trichotropis borealis*, *Trophon clathratus* (typical), *T. latericeus*, and *Pleurotoma pyramidalis*; the first, third, fourth, fifth, seventh, and three last are Norwegian and not British. These species represent a depth of from ten to twenty fathoms. The other species are littoral, or inhabit shallow water; and I believe they still live in Carnarvon Bay. All the organisms are more or less fragmentary, perhaps owing to glacial action. They are all together 63; but that number might be considerably increased by future observers.

Discussion.

The President pointed out that one great value of this paper consisted in its giving a complete list of the very fragmentary forms found in the Moel-Tryfan beds.

Mr. W. W. Smyth said that fossils had not been found in any of the superficial deposits on the flanks of Moel Tryfan; the hill has been rendered easily accessible by a narrow-gauge railway.

Prof. T. M'K. Hughes asked the author if he distinguished between those deposits in which the shells appeared not to have drifted far from their habitat and those in which, as in the case of Moel Tryfan, they were evidently the dead shells thrown up on a shingly shore. He drew attention to the fact that the flints &c. in the Moel-Tryfan beds, apparently derived from the destruction of ancient gravels, pointed to a travelling beach; and the state of the shells, very few of which were whole, agreed with this view.

Mr. Whitaker asked if the author had attempted to compare the sands with shells of East Anglia with those of Moel Tryfan.

Mr. Blake objected to the views of Dr. Carpenter, by pointing out that the Chalk, which is said to be a deep-water formation, yet exists at considerable heights above the present sea-level.

Dr. Woodward referred to the value of the collection of shells of existing species found at great elevations by the recent Arctic Expedition.

The President stated that some very delicate shells were found entire and uninjured at Moel Tryfan.

The Author (in reply) said that the Moel-Tryfan deposit was not strictly a glacial one. The fauna has a Norwegian rather than an Arctic facies. The broken appearance of shells may be due to other causes than glacial action. He stated that some of the Moel-Tryfan shells (e.g. *Tellina balthica*) are quite perfect.

26. *A* Review *of the Family* Diastoporidæ *for the purpose of Classification.* By George Robert Vine, Esq. (Communicated by Prof. Duncan, M. B. Lond., F.R.S., F.G.S.) (Read May 12, 1880.)

[Plate XIII.]

The Diastoporidæ are a group of adherent Polyzoa belonging to the suborder Cyclostomata. Busk defines the generic characters thus:—"Zoarium crustaceous or foliaceous, discoid or indefinite in outline; adnate and sessile, or pedunculate and erect; *no cancelli*"*. This restricted definition limits the group to almost a single genus; for the *Mesenteripora* of Blainville is the only other genus classed by Smitt and Busk among Diastoporidæ, and the non-cancellated surface separates this small family from the Discoporellidæ.

In this review of the recent and fossil Diastoporidæ we must bear in mind the restriction formulated by Busk, because as we go backward in time the necessity of this caution will be apparent. The family was never prolific either generically or specifically; but in nearly all the seas, from the Lower-Silurian era to the present, representatives of the family are generally found in deep-sea deposits. Their geographical range now is chiefly northern; and their bathymetrical range in the past was as variable as now.

In his definition of the genus *Diastopora*, Busk says:—"Zoarium adnate, discoid or flabelliform, centric or excentric, margin entire or lobed; cells towards the centre wholly immersed, usually suberect, and partially free towards the margin; mouth elliptical or suborbicular, horizontal or oblique"†. As there is no typical species in which the whole of these characters are preserved, we are compelled to seek them in the five species catalogued as recent and fossil by Busk. But there are specific characters not embraced in the generic definition, to which I wish to direct attention. In *D. simplex* the surface is *coarsely* punctate, and there are no "adventitious tubules." In *D. obelia*, Johnst., the surface is finely punctate, and a small "adventitious tubule rises from the back of some of the cells." In *D. patina*, Lamk., the central cells are immersed and usually closed, whilst the marginal ones are erect and open; and in *D. congesta*, D'Orb., the cells are decumbent, the surface is spotted, and a secondary disk arises from the surface of the primary one. In pl. xxxiv. of the 'Cyclostomata,' Busk gives a figure of *D. sarniensis*, Norman, but no descriptive text. Norman, however, claims for this species a separate identity; but the most characteristic feature is its size, "and here and there among the open-mouthed cell-tubes there occurs a tube which, instead of being open, is closed above with a little cup, from one side of the centre of which rises an umbonal-like process, which is perforated at the apex. Probably these organs

* Mus. Cat., pt. iii. Cyclostomata, p. 27. † Ibid. p. 28.

are connected with the reproduction of *Diastopora,* and are homologous with ovicells"*.

These are all the recent and fossil *Diastoporæ* given by Busk in the 'Cyclostomata' and in the 'Crag Polyzoa.' Mr. Waters, in his papers on the Naples "Bryozoa" † and in his paper on the "Bryozoa from the Pliocene of Sicily "‡, revives one of the synonyms of Busk's *D. obelia*, the *D. lato-marginata* of D'Orb., and adopts *D. flabellum*, Reuss, in the place of *D. simplex,* Busk, on the ground that D'Orbigny had already appropriated the term for a fossil species §.

In this review of the family I wish to direct the attention of the *palæontologist* more particularly to the Palæozoic forms; but it may be advantageous as a more accurate study if I give a stratigraphical list of the fossil Diastoporidæ, gleaned from works that are accessible to me; for the remarks made upon the species from Recent to the Chalk, and from the Carboniferous to the Upper Silurian, are the results of original investigation.

RECENT.	Species already given.
POST-TERTIARY.	*Diastopora obelia*, Flem. Garvel Park, Scotland.
PLIOCENE.	—— *simplex*, Busk's 'Crag Polyzoa,'
	—— *meandrina*, Wood, Mor. Cat.
	—— *flabellum*, Reuss, Waters's 'Bryozoa of Naples.'
MIOCENE.	—— ——, Reuss, Manzoni's 'Bryozoi d'Aust.'
UPPER CHALK.	—— *grandis*, D'Orb., "*D. ramosa* very doubtful."
	—— *Sowerbii*, Lonsd., Mor. Cat.
	—— *Wetherelli*, Morris, Mor. Cat.
	—— *glomerata* and *congesta*, D'Orb., Busk's Cat.
GREENSAND.	—— *clavula*, D'Orb., Mor. Cat.
	—— *tuberosa*, D'Orb., Mor. Cat.
	—— *papyracea*, D'Orb., Mor. Cat.
OOLITE.	*Berenicea foliacea*, Lamx., Mor. Cat.
	—— *verrucosa*, Milne-Edw., Mor. Cat.
	—— *diluviana*, Milne-Edw., Mor. Cat.
	—— *Eudesiana*, Milne-Edw., Mor. Cat. ‖
LIAS.	—— *striata*, J. Haime. Lias of Valica ¶.
?	—— *antipodium*, Tate, African form **.
CARBONIFEROUS.	—— *megastomus*, M'Coy, 'Irish Fossils.'

* Ann. & Mag. Nat. Hist., January 1864.

† Ann. & Mag. Nat. Hist., April 1879, p. 272.

‡ Manchester Geol. Soc. Trans., May 1878.

§ The Rev. T. Hincks, in his new work on British Polyzoa, does not admit the rendering of Mr. Waters, but gives a new name, *D. suborbicularis*, to *D. simplex* (Brit. Polyzoa, vol. i. pp. 464 to 466).

‖ *Elea* and *Bidiastopora*, D'Orb., require reworking; and I shall be glad if palæontologists will help me in this matter.

¶ If *Berenicea striata*, J. Haime, of the Lias of Valica, may be taken as the type of our foreign Secondary rocks, it may be taken also as the type of our own Oolitic species. I have not seen Haime's figure; but Manzoni, in his 'Briozoi del Pliocene antico di Castrocaro,' gives good figures of *Diastopora* (*Berenicea*) *striata*, J. Haime (p. 44, tav. vi. fig. 74, and tav. vii. fig. 79), which very closely resemble our species from the Inferior and Great Oolite of Cleeve and Kidlington.

** Quart. Journ. Geol. Soc. 1867, p. 162. "The only Polyzoon hitherto known in the Secondary rocks of South Africa."

Devonian.	*Ceramopora huronensis*, Nicholson, Geol. Mag. 1875.
Silurian, Upper.	—— *incrustans*, Hall, Pal. of New York, vol. ii.
	—— *ohioensis*, Nicholson, Ann. of Nat. Hist. 1875.
	Berenicea irregularis, Lonsd., Sil. Syst. p. 679, pl. 15. fig. 20.
Silurian, Lower.	—— *heterogyra*, M'Coy, Pal. Foss. pl. i. *c*. fig. 17.

It is impossible to look over this list without some sense of shame that this indiscriminate nomenclature should be allowed to influence the minds of those who undertake the task of introducing to the palæontologist new species of fossil Diastoporidæ. Between the *Berenicea* of Lamouroux, the *Ceramopora* of Hall, and the *Diastopora* of Smitt and Busk there is a wide difference—so much so that, though all the genera are incrusting, there are special features about the Palæozoic that are not found in the Secondary, Tertiary, or recent forms. For the present many of the species in this list may be conveniently left with the Diastoporidæ; but I would strongly advise those who are in possession of good characteristic specimens of Secondary forms to allow them to be examined by some competent authority, so that this review may be completed, because some few that are catalogued are not *Diastopora* or even Diastoporidæ.

The generic characters of Lamouroux's *Berenicea*, as given by M'Coy, are as follows:—"Parasitic: cells united in a spot-like crust, radiating from a centre; adhering throughout, not circumscribed; mouth at the distal extremity of each cell; substance *submembranaceous*"*. In the 'Brit. Pal. Fos.' p. 44, M'Coy very properly checked Lamouroux's wider characters; and his description of the genus suits more particularly some at least of the Palæozoic forms. The *B. heterogyra*, M'Coy, of the Lower Silurian rocks of Coniston, is a remarkable species. From his description it seems to me to be a true Diastoporid of a very peculiar type; but the size of the cells in the length (three to the space of one line), occupying the same space as the ten or eleven pores crosswise, is very unusual. M'Coy says nothing about the interspaces between the cells in his species. The *B. irregularis* of Lonsdale is very insufficiently described; but as the locality of his fossil is given (Dudley), identification is not so difficult. The species, however, requires reworking: and in doing this I find that the cells are very sparsely punctate; and when sections are made for microscopic examination, the interspaces between the cells of this species are plain, and the mode of bifurcation and the attachment of the cells are also of a peculiar type. The cell-pores, too, are not so fully developed as in the genus *Ceramopora*, nor are the cell-mouths so distinctly marked. It seems to me, however, to be a very unwise procedure to substitute another name for these Silurian species; I therefore propose that M'Coy's definition for the genus in 'Brit. Palæozoic Fossils' be adopted, and entirely restricted to the "very thin calcareous foliaceous" forms of the Silurian rocks of this country at least.

In the genus *Ceramopora*, Hall, we have an altogether different type of the family Diastoporidæ. In this genus we have an incrusting polyzoon with pores separated by interspaces as well as the

* Carb. Foss. of Ireland, 1844.

cell-walls, the interspaces being occupied by fine tubuli. In size and shape the American species do not differ very materially from the Dudley *Berenicea*; but in Nicholson's *C. ohioensis** we obtain an altogether new feature. The cell-arrangements of figs. 7 and 7 *a* are similar in character, when favourably selected, to those of Carboniferous species. The true type is seen in figs. 7 *c* and 7 *d*. In these figures "the cells appear in the form of rounded oval apertures, arranged in diagonal rows, but separated by a vast number of small rounded foramina, which appear to be the mouths of interstitial tubuli. In this condition the fossil presents much the appearance of certain species of *Chætetes* (*Monticulipora*)"†. This is a Silurian form from the Cincinnati group. The *C. incrustans* of Hall has a nodulose or tuberculated surface; and in the *C. huronensis*, Nicholson, the surfaces between the cells are smooth, but the cells are distinctly separated, and the generic character of the species is well marked in the pores.

All these species are comparatively small in the apertures when compared with the *Berenicea megastoma* of M'Coy, of the Carboniferous formation (Pl. XIII.). This species is more closely allied to *Ceramopora* than to *Berenicea*. The patches vary in size from one quarter up to nearly three quarters of an inch in diameter. The patches radiate from a centric or excentric point. The cells toward the centre are depressed, the cell-mouths are raised, having a circular form when worn, triangular when pretty perfect. The cells have a pyriform appearance, best seen in worn specimens; but when thin sections are made for microscopic study, the pyriform character is seen better still, and the interspaces are filled with what Nicholson calls "interstitial tubuli." In addition to these observations I cannot do better than conclude this description with a few remarks by Mr. John Young on this species:—"Our specimens show the characters of M'Coy clearly; but I have been fortunate in finding in the shales of Capelrig, East Kilbride, examples of the species showing, besides, that the perfect cells were closed by a thin calcareous cover, pierced by a narrow slit or opening, just under the raised lip of the cell, and, further, that amongst the cells there is a minute cellular structure, best seen in slightly worn specimens"‡. In this, as well as in other respects, the Capelrig species differs from the well-preserved specimens from Hairmyres; and in one of my specimens a secondary disk rises, or, rather, covers a portion of the primary one. The arrangement of the cells and the thin calcareous surface-covering are also different. It appears, therefore, that we have in our Carboniferous Limestone series two distinct species instead of one.

The Secondary forms of the Diastoporidæ approach nearer to the Recent than to the Palæozoic; but on these I have already expressed my opinion.

It is clear, then, from all that has been said, that the Palæozoic representatives of the family Diastoporidæ differ very materially from

* Ann. & Mag. Nat. Hist. 1875, vol. xv. pl. xiv. figs. 7–7 *d*.
† Ibid. p. 183.
‡ Newspaper report. Address to the Geol. Soc. of Glasgow, Oct. 1879.

the more recent members. If the whole are to be classified under one family name, a course highly advantageous to the study of Polyzoa, it will be necessary to take into consideration the more prominent characters, and place the species of the different formations under suitable genera. I have already suggested this course to Prof Nicholson; and he writes me as follows:—"The Palæozoic Polyzoa of the types *Ceramopora*, *Berenicea*, and *Diastopora* are at present in a totally chaotic condition, and must all be reworked out by modern methods." In accordance with this suggestion I now propose, either for acceptance or discussion, the following grouping of the family, premising at the same time that the whole of the Palæozoic Polyzoa are being reworked out by myself for the purpose of classification, and, if permissible, will be submitted, from time to time, to the Society for consideration.

Class POLYZOA, J. V. Thomson.

Subclass HOLOBRANCHIA, E. Ray Lankester.

Order GYMNOLÆMATA, Allman.

Suborder II. CYCLOSTOMATA, Busk.

Family IV. DIASTOPORIDÆ, Busk*.

Recent and Tertiary..	Genus	I. *Diastopora*, Johnston.
Secondary..........	,,	II. To be reworked.
Palæozoic (in part) ..	,,	III. *Ceramopora*, Hall†.
Palæozoic (in part) ..	,,	IV. *Berenicea*, M'Coy's description restricted.

EXPLANATION OF PLATE XIII.

Fig. 1. *Ceramopora megastoma* (*Berenicea*, M'Coy), Lower Carboniferous Limestone shales, Hairmyres, Scotland. The common adherent form. In some specimens the "ectocyst" is well preserved in fragments; when this is so, a delicately punctured structure envelops the cells.
2. Slightly rubbed polyzoary, showing the "interstitial tubuli" of Nicholson ("Polyzoa from Silurian Rocks of North America," Ann. & Mag. Nat. Hist., March 1875).
3. Specimen, more transparent, showing a greater abundance of the "tubuli."

Figs. 4, 5. Slightly oblique cells and interstitial tubuli. In many of the tubuli there are the remains of fluids (chylaqueous?), in the form of iron-pyrites.

(From drawings by the aid of camera lucida by my son, G. R. Vine, jun.)

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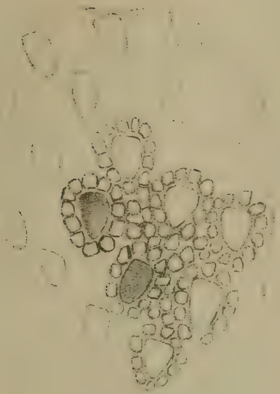
* Fam. IV. *Diastoporidæ*, Busk, 'Marine Polyzoa,' pt. 3.
† *Ceramopora*, Hall, Pal. of New York, vol. ii. 1852.

2.



x 20.

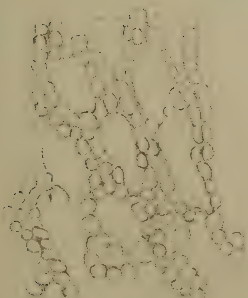
3.

x 20.

1.

x 12.

4.



x 20.

5.

x 20.

A. S. Foord. lith

Mintern Bros. imp.

CERAMOPORA MEGASTOMA.

Discussion.

Prof. Duncan expressed his sense of the value of the paper, which was the work of a most industrious student. His remark on the distinction between the modern and ancient forms of Diastoporidæ showed that he had grasped the most important principle. The specimens were common; but still the distinctions were difficult to ascertain.

27. *On the* Structure *and* Affinities *of the Genus* Protospongia (*Salter*). By W. J. Sollas, Esq., M.A., F.R.S.E., F.G.S., &c. (Read May 12, 1880.)

1. Literature.

1864, Salter, Q. J. G. S. vol. xx. p. 238, pl. xiii. fig. 12 *a*, *b*.
1871, Hicks, Q. J. G. S. vol. xxvii. p. 401, pl. xvi. figs. 14 to 20.
1877, Zittel, Abh. der k. bayer. Akademie der Wiss. 2. Cl., xiii. Bd. "Studien ü. fossile Spongien" (p. 45 sep. copy).
1877, Carter, Ann. and Mag. Nat. Hist. Ser. 4, vol. xx. p. 177.

2. History.

Salter, who was the first to introduce this Sponge to our notice, describes it as exhibiting a loosely reticulate skeleton, composed of large cruciform spicules, the rays of which lie all in one plane and cross each other at an angle of 80°. He adds that the only sponge resembling it is his *Amphispongia*, which he regards as allied to *Grantia*—a view quite in accordance with his ideas in general on the Palæozoic sponges, most of which he seems to have referred to the Calcispongia. In a foot-note he gives a quotation from a letter by Dr. Bowerbank, who, in equal accordance with his general opinions as to the affinities of fossil sponges, regarded *Protospongia* as allied to the recent horny sponge *Spongionella*, Bwbk., its orginally horny fibres having, according to him, been replaced by iron-pyrites.

Hicks describes some spicular remains which he thinks may belong to *Protospongia*, and gives a diagrammatic figure of a fine specimen which he had discovered of Salter's original species, *P. fenestrata*.

Zittel places these Sponges with the Hexactinellidæ, and in his group Dictyonina, which is nearly equivalent to Carter's Vitreo-hexactinellidæ. He further more closely defines its relations by placing it in the family Euretidæ. Certainly the resemblance of the ordinary specimens of *Protospongia* to my *Eubrochus clausus*, also a member of the Euretidæ, is very great, and at one time, long before the publication of Zittel's monograph, led me to regard them as allied; fresh facts, however, have since shown me that this view is not correct.

Carter considers it probable that both *Acanthospongia* of McCoy and *Protospongia* of Salter are the remains of Sarco-hexactinellid sponges. This view, as regards the latter, is entirely confirmed by my own observations.

Through the kindness of Professor Hughes I have been favoured with an opportunity of fully examining the unique and beautiful specimen of *Protospongia fenestrata* which has been figured by Dr. Hicks (*loc. cit.*) and presented by him to the Woodwardian Museum, Cambridge. Dr. Hicks also has himself generously presented me with a number of the ordinary specimens of *Protospongia*; and after a study of the whole of the material which has come under my observation, I feel no difficulty in definitely assigning to *Protospongia* its place amongst the other sponges. Moreover, as Dr. Hicks's figure of his specimen is almost purely diagrammatic, I have ventured to insert here a fresh drawing of part of it, kindly made for me by my friend Mr. T. H. Thomas, of Cardiff. The great interest which must necessarily attach to the best-preserved specimen of the oldest known sponge renders excuse for this second representation of it needless.

3. Description.

The specimens on which Salter's description was based were crushed and flattened forms in which the skeleton appears as raised lines or narrow thread-like ridges arranged in a lattice-like reticulation on the bedding-planes of the slate which serves as a matrix. Dr. Hicks's specimen (fig. 1), on the other hand, presents us with the

Fig. 1.—*Part of the specimen of* Protospongia fenestrata, *in the Woodwardian Museum.* (Natural size.)

spicules of the sponge in their original form, unaltered, or but slightly altered by pressure, and standing out in free relief from the weathered matrix, which has in several places been artistically cleared away from beneath them.

In this state of perfect preservation the spicules are clearly not fused together into a continuous network; they are separated and free, and only form a network by the interlacing of their extremities. Their form also is somewhat different from that of the spicules of crushed specimens.

Form of the Spicules.—Each spicule is quadriradiate, with its centre raised some slight but variable distance above the plane in which its rays terminate. Its general form may be most easily described by imagining it as modelled upon a low four-sided pyramid, the centre of the spicule lying upon the apex, and its four rays one over each of the four inclined edges of the pyramid. The base of the pyramid must be regarded as rectangular, a little longer than broad; for even in the uncrushed state the rays of the spicules do not form right angles with each other, but include one pair of opposite angles of less, and another of more than 90°. Probably, however, this departure of the rays from strict rectangularity is due to the pressure which brought about the cleavage of the slate in which the spicules occur; for it is noticeable that the spicules of any single specimen are all similarly orientated; *i.e.* the larger angles all look one way, and the smaller another, as if some general distorting force had acted upon all the spicules at once, closing up the rays in one direction and opening them out in another.

Four rays are all that each spicule can be shown to possess; but a fifth might naturally be expected to be present, having its origin from the under surface of the spicular centre, and a position coinciding with the morphological axis of our imaginary pyramid. Whether such a ray actually exists or not, I have been unable to determine, though certain obscure indications lead me to believe that it does. On the other hand, it is quite clear that no ray was given off in the opposite direction, *i. e.* from the upperside of the middle of the spicule upwards; for this side is perfectly preserved and clearly visible, and yet affords no trace of the existence of such of a ray; it has evidently been always as smooth and devoid of ornament as it is now.

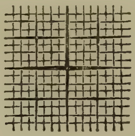
The spicular rays are quite circular in section and almost completely cylindrical in form, scarcely tapering at all, so far as they can be traced—except in the case of the smaller spicules, the rays of which are evidently acute cones; none of the spicules, however, shows the ultimate termination of a single ray; for the ends of the rays are either broken off, imbedded in the slate, or hidden by passing beneath the arms of adjacent spicules. In size the spicules are of four different grades: in the largest forms the spicular rays are $\frac{13}{40}$ of an inch long, so that the whole spicule measures as much as $\frac{26}{40}$ of an inch between the ends of two opposite rays; in the second-sized spicule the rays are $\frac{6}{40}$ of an inch long, in the third $\frac{3}{40}$, and in the fourth size $\frac{3}{80}$ of an inch long; thus each spicule is twice the size of the one next succeeding it in the scale.

Arrangement of the Spicules.—The largest or primary spicules form a framework, which is filled in by the smaller forms. The secondary spicules are placed so that the centre of each coincides with the centre of the square which would be formed by completing the rectangle included between the adjacent rays of the primary spicule. The four rays of the secondary spicule proceed from their origin directly towards and at right angles to the sides of the imaginary square, one to each side; those which approach the rays of the primary spicule descend beneath them and become lost to observation. The tertiary spicules are similarly arranged; but in their case the squares within which they lie are chiefly real and not imaginary, some of the squares being formed by two rays of the primary and two of the secondary spicules, others having two sides formed by the secondary rays, and one by a primary ray. [The imaginary square of the primary spicule may have been, and probably was, equally actual; but in the specimen before us there is nothing to show this.]

The rays of the tertiary spicules end by passing beneath the rays of the primary or secondary spicules, just as the rays of the secondary passed beneath those of the primary spicules.

The quaternary spicules are arranged in like manner, their centres lying in the centres of the squares formed by the other spicules, and their rays being directed at right angles to the other rays, beneath which they terminate. Sometimes, however, one or more rays of a quaternary spicule overlap, while the remainder underlap, the rays of the surrounding spicules; but this is quite exceptional. The spicules are thus symmetrically arranged, their rays all lying regularly disposed in two directions at right angles to each other, and so building up a network with square meshes. The following figure (fig. 2) will serve as a diagram of this arrangement.

Fig. 2.—*A single large spicule of* Protospongia, *with the smaller spicules filling its interspaces.*



One notices in Dr. Hicks's specimen a tendency to depart from strict rectangularity in the meshes, through a general approach of the spicules at one end of the specimen and a general divergence at the other, as though the part of the skeleton exposed had once belonged to a more or less spherical sponge, and not to one having the form of a mere flat film or plate. The symmetry of the arrangement is also liable to be disturbed by many minor irregularities, a few of the smaller spicules being more or less differently oriented from the remainder. In one case also the centre of a quaternary spicule appears to be seated almost exactly upon the ray of one of the larger forms, from which one might infer that this particular spicule, at all events, did not posses a fifth ray.

Thickness of the Sponge-wall.—As regards this we have as yet no certain knowledge; but it appears to have consisted of more than one layer of spicules. In the specimen two layers of sponge-structure are shown at different levels, separated by a little "cliff." But not much is to be concluded from this; for the 'cliff' may be merely due to a 'slip' or minute fault which has shifted an originally single layer of sponge-structure to different levels; or even if this be not the case (and the presence of a layer of iron-oxide continuing the direction of the lower layer beneath the upper seems to show that it is not), there still remain three possible interpretations of the double layer: the sponge, for instance, may have been thin-walled and sacciform, and its collapse may have brought the walls of opposite sides close together; or it may have been an incrusting flat film, and the two layers may indicate the successive growth of two different individuals on the same spot; or, finally, the two layers may represent the outer and inner surface of one and the same sponge-wall, which in this case must have been of some considerable thickness.

Form of Sponge.—Of this also we are entirely ignorant. It may have been flat and incrusting; or, on the other hand, it may have been sacciform and anchored in the slimy ooze of the sea-bottom by a tuft of anchoring spicules, of which Dr. Hicks's *Protospongia major*, may be the imperfectly preserved remains.

Mineral State of the Spicules.—Without doubt the spicules were originally siliceous; they consist now, however, of iron-pyrites, which, by superficial oxidation, has led to the coating of the spicules with a thin red layer of iron-rust.

Taxonomic Position of the Sponge.—The position of the sponge with regard to others is by these observations definitely fixed. It consists of cruciform spicules of various sizes disposed to form a regular square meshwork, the rays of the smaller spicules underlying at their terminations the rays of the larger ones. Such spicules so disposed are to be met with among the Hexactinellid Sponges alone; the absence of one (or possibly two) of the rays which should be present to render the spicules literally hexactinellid is of no importance; in several characteristic forms of recent Hexactinellids similar spicules are common, along with others of the genuine sexradiate type. The suppression of one, two, three, or even four arms of the hexactinellid spicule may easily take place without affecting its undoubted Hexactinellid character.

Again, the spicules of *Protospongia* are separate; they are not united either by envelopment in a common coating or by ankylosis; and hence they must clearly be assigned to the Lyssakina of Zittel, a group nearly equivalent to Carter's division of the Sarco-hexactinellidæ.

The nearer relations of *Protospongia* cannot at present be defined. Its chief differences from other Lyssakine Hexactinellids depend on negative characters, and consequently may very possibly be but the expression of our present imperfect knowledge of its original nature. For the present we must rest content with the knowledge of the fact that it is a true Lyssakine Hexactinellid.

Discussion.

Prof. Duncan expressed his pleasure at hearing so good a description of an ancient sponge. We were much indebted to Bowerbank, Carter, Zittel, and Mr. Sollas for their work among the sponges. He had himself obtained from a coral dredged from about 500 fathoms in the Atlantic a sponge which presented some analogies to *Protospongia*. He would be glad to know if Mr. Sollas thought *Protospongia* part of the dermal structure of a large sponge.

Dr. Hicks described his discovery of *Protospongia*. He had never found it otherwise than pyritized. This condition, he had observed, was particularly common in fossilized horny organisms in the Cambrian rocks.

The President remarked on the abundance of pyritized remains at certain horizons, and on the value of the collection made by Dr. Hicks from the Cambrian rocks.

Mr. Sollas said he inclined to the view that *Protospongia* was part of the dermal structure; but still it was strange that no other part was found, and so far as the evidence went it was quite as strong for the sponge being complete. As for the occurrence of pyritized fossils, one might expect that under similar circumstances fossils would be similarly preserved.

28. *On* Annelid Jaws *from the* Wenlock *and* Ludlow Formations *of the* West *of* England. By George Jennings Hinde, Esq., F.G.S. (Read May 12, 1880.)

[Plate XIV.]

In the paper which I had the honour to bring before the Society in the early part of last year, on Annelid jaws from the Palæozoic rocks of Canada and Scotland*, I ventured to express an opinion that these small bodies would be very likely found in rocks of similar age in this country. Since that time I have had the opportunity of searching various exposures of the Silurian rocks at Dudley, Much Wenlock, and Iron Bridge, in Shropshire, all well-known localities for Wenlock fossils; and in each place I have discovered Annelid jaws more or less abundantly. In quarries at Stoke-Edith, and near Ludlow, the rocks of Upper Ludlow age also yielded these remains, though by no means so abundantly or in such a good state of preservation as the Wenlock rocks—a result perhaps rather owing to the less favourable character of the matrix for their preservation and to the more limited exposures of the rock-surfaces than to any deficiency in the number of the Annelids. Altogether, from the above-mentioned localities my search produced between two and three hundred specimens of these minute remains: but the greater number of these proved on examination to be only fragmentary specimens; many perish in the process of cleaning them away from the matrix; and thus only about one fourth of the total number are available for description. It is a matter of surprise that these fossils, occurring thus numerously in a district renowned as a classical hunting-ground for Silurian fossils, should hitherto have escaped the notice of geologists; but their very small dimensions (the largest specimen met with not exceeding one fifth of an inch in length) will sufficiently explain the cause of their long concealment.

The character of the rocks containing these jaws is closely similar to that in which they abound in Canada. In the Wenlock district they appear in the bluish-grey calcareous shales or mudstones which form strata of greater or less thickness between the beds of limestone; and in quarrying this rock these intervening shales are usually piled up on one side in large mounds of débris. It is only on the surfaces of shale recently exposed that these fossils are visible; nor are they by any means uniformly dispersed in it; for whilst in one part of a quarry fragments can be noticed on every slab of rock, in another part of the same quarry similar shale proves destitute of all traces of them. The Upper Ludlow rocks, as shown in quarries at Stoke-Edith and on the banks of the river Terne at Ludlow, are more arenaceous and of a much harder character than those of Wenlock age; and consequently these fragile remains have

* Quart. Journ. Geol. Soc. vol. xxxv. p. 370.

suffered more injury than in the deposits of finer material. There are in these same Upper Ludlow strata the shelly tubes of *Serpupulites longissimus*, Murchison, and the transversely striated riband-like markings of *Trachyderma coriaceum*, Phillips, both of which forms have been referred to Annelids; but I have not met with any of the jaws in such juxtaposition with either of these fossils as to give ground for the supposition that they may have belonged to the same animals.

In respect to the *condition* in which these jaws occur, there is a close correspondence with the American forms. They are composed of the same brittle chitinous material, and when unweathered they have the same glossy black lustre. Unfortunately, also, they have been similarly detached from their natural positions and individually scattered in the muddy sediments, so that there is the same difficulty about their satisfactory classification. In addition to the minute bodies which can be definitely determined to be portions of the mouth-apparatus of Annelids, there are on some of the rock-surfaces numerous minute, dark, chitinous fragments, of no definite shape, which are not improbably portions of the skin of the same animals. Similar fragments are also present in some of the American rocks; and if they are rightly referred to the horny integument of these Worms, these animals must have possessed a greater amount of chitin in their skins than their modern congeners, whose body-covering is of such a delicate character as to render it very unlikely to leave any traces in the fossil state. Judging from the quantity of these fragments, and the number of the jaws, the Errant Annelids must have been very abundant, at least locally, in the Silurian period.

Whilst there is a similarly great variety of *form* in the English fossil jaws, there is no striking difference from those already described from America, but, on the contrary, a most remarkable resemblance, considering the great distance which intervenes between the respective localities whence they come. Equally remarkable, as proving the persistency of form and wide dispersion of these animals, is the fact that whilst some forms are common to the relatively equivalent Clinton and Niagara rocks of Canada, an equal number of these jaws are identical with those from the older Cincinnati group of America, a formation generally regarded as the equivalent of the Bala of this country. Even in the jaws which I regard as distinct from the American forms, it will be seen, on comparing the appended description and figures with those of the former paper on the subject, that the variations are but small in amount, and principally depend on minor differences of form. As a rule, the dimensions of the jaws, even of those of the same species, are less than in the American examples, the largest English specimen met with not exceeding $2\frac{1}{8}$ lines in length, whilst some of the American forms are $3\frac{1}{2}$ lines long.

In classifying these jaws I have adopted the same grouping as in my former paper, not, however, without being thoroughly conscious of its tentative character, as serving for palæontological reference rather than as presenting exact zoological arrangement. Independently of the difficulties arising from the detached positions of the particular jaws which compose the mouth-apparatus of the same animal, it would appear, if we may judge from their great variations in existing Annelids, that these organs are very insufficient for a basis of classification. On this point M. Claparède, one of the greatest authorities on recent Annelids, makes the following remarks *:—"If it is possible to make use of the jaws in a certain measure as characteristic of the tribal divisions, on the other hand their employment appears impossible, or at least very difficult, for the limitation of the genera; and I acknowledge that this fact surprises me. On one hand very different jaws are met with in the same genus; on the other, identical jaws are frequent in different genera."

As there is every indication that the Silurian Annelids possessed the same variations in their mouth-apparatus which thus characterizes the living members of the same order, it will be seen that, in the absence of other recognizable structures, much uncertainty must inevitably attend the arrangement of these fossil jaws under different generic divisions.

In addition to giving descriptions of new forms, I have deemed it useful to make brief references to show which have been already described from the American rocks.

ANNELIDA POLYCHÆTA.

Genus Eunicites, Ehlers.

Eunicites major, Hinde.

Eunicites major, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. plate xviii. fig. 1.

The only English specimen of this species met with is less truncate posteriorly, has more acute denticles, and is smaller than the generality of the typical forms from the Cincinnati group. Its length is $1\frac{1}{6}$ line, width $\frac{1}{2}$ line.

Locality and formation. Wren's nest, Dudley: Wenlock group.

Eunicites curtus, Hinde. (Pl. XIV. fig. 1.)

Jaw consisting of an oblong compressed plate, widest in the anterior portion, the posterior end truncate, the base nearly straight; on the upper margin a series of twelve denticles, the first six of which are subequal, blunted, and nearly upright, and the others pointed and directed backwards. Length 1 line, width $\frac{1}{4}$ line. This form is allied to *E. varians*, Grinnell, sp., but is shorter, more compressed, and with fewer denticles.

Loc. and form. Much Wenlock: Wenlock group.

* Annelides Chétopodes du Golfe de Naples, p. 24.

EUNICITES VARIANS, Grinnell, sp.

Nereidavus varians, Grinnell, American Journal of Science, Sept. 1877, p. 229.

Eunicites varians, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 375, pl. xviii. figs. 2, 3, 5.

The examples of this species correspond with the American forms in almost every respect, save that they are of much smaller size. The jaw is nearly straight; the anterior portion is slightly convex and incurved, and the posterior end blunted. On the upper margin there are from ten to eighteen teeth, of which the first three or four are nearly upright and rounded, and the others more or less acute and directed backwards. In some of the specimens there are indications of a small rod or support attached to the inner side of the anterior portion of the jaw, of a similar character to the flangelike base occurring in the genus *Lumbriconereites*. The specimens vary from $\frac{5}{8}$ line to 1 line in length.

Loc. and form. Wren's Nest, Dudley: Wenlock group.

EUNICITES CLINTONENSIS, Hinde.

Eunicites clintonensis, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 381, pl. xix. fig. 21.

Less difference exists between the forms of this species and *E. varians* than in the Canadian examples of the two species. In *E. clintonensis*, however, the anterior portion is more elevated and the denticles are more uniform than in *E. varians*. There is a great resemblance also between this species and *Lumbriconereites basalis*, H.; but this latter has a wide basal flange supporting the ridge which carries the denticles. This flange is not always exposed to view; and it is probable that some at least of the examples referred to *E. clintonensis* may really possess the flange which is distinctive of the genus *Lumbriconereites*.

The average length of the specimens is 1 line.

Loc. and form. Much Wenlock; Wren's Nest, Dudley: Wenlock group.

EUNICITES CORONATUS, Hinde.

Eunicites coronatus, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 381, pl. xx. fig. 9.

The examples of this form are somewhat smaller, less convex, and with two or three more denticles than the forms from the Clinton rocks of Canada. They closely resemble the "paragnaths" in the recent genus *Eunice*. Length $\frac{5}{8}$ line, depth $\frac{3}{6}$ line nearly.

Loc. and form. Wren's Nest, Dudley: Wenlock group.

EUNICITES CHIROMORPHUS, Hinde, var. minor. (Pl. XIV. fig. 10.)

Jaw triangular, strongly convex, the sides gently curved, on the upper margin six upright blunted teeth. Length of upper edge $\frac{1}{2}$ line, depth $\frac{3}{8}$ line nearly. This variety is much smaller, less extended, and with fewer denticles than *E. chiromorphus*.

Loc. and form. Wren's Nest, Dudley: Wenlock group.

EUNICITES UNGUICULUS, Hinde. (Pl. XIV. fig. 11.)

Jaw somewhat semioval, flattened, or slightly concave; the base straight, with a small oblique projection at the anterior end; an arched upper margin, with nine denticles, of which the two largest are slightly incurved. Length $\frac{1}{2}$ line, depth $\frac{1}{4}$ line. This form, like the two preceding, appears to have been one of the "paragnaths," or small anterior jaw-plates of the animal.

Loc. and form. Wren's Nest, Dudley: Wenlock gronp.

Genus ŒNONITES, Hinde, 1879.

ŒNONITES REGULARIS, Hinde. (Pl. XIV. fig. 2.)

Jaw subtriangular, compressed, with a slightly projecting knob-like elevation at the angle in the centre of the base, a prominent curved hook at the anterior end, the upper margin straight and carrying a series of thirteen teeth. Length 1 line, width $\frac{3}{8}$ line. This form is allied to *Œ. cuneatus*, H., from the Cincinnati group, but differs in its more triangular outline, the elevation at the basal angle, and its larger size.

Loc. and form. Wren's Nest, Dudley: Wenlock group.

ŒNONITES NAVIFORMIS, Hinde. (Pl. XIV. fig. 3.)

Jaw oblong, compressed, the basal margin curved and having a small notch in the centre, the posterior end truncate; the anterior tooth bent slightly out of plane with the plate of the jaw; on the nearly straight upper margin are ten blunted denticles. Length 1 line.

This form is closely related to *Œ. amplus*, H., from the Clinton group of Canada, from which it is distinguished by the uniform series of teeth and the notched base.

Loc. and form. Wren's Nest, Dudley: Wenlock group.

ŒNONITES CUNEATUS, Hinde.

Œnonites cuneatus, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. pp. 377, 381, pl. xviii. fig. 11.

The English examples of this form, with the exception of a slight difference in the curvature of the anterior hook and a less number of the minute denticles, are identical with those from the Cincinnati and Clinton formations of America. The specimens do not exceed half a line in length.

Loc. and form. Iron Bridge, Shropshire; Wenlock group.

ŒNONITES CUNEATUS, Hinde, var. HUMILIS. (Pl. XIV. fig. 6.)

Jaw semioval, compressed, with a delicate anterior hook, slightly bent outwards, and on the nearly straight upper margin of the jaw 11 subequal denticles. The variety differs from the typical *Œ. cuneatus* in the relatively smaller anterior hook, which is followed, without any interval, by the smaller denticles. Length $\frac{1}{2}$ line.

Loc. and form. Iron Bridge; Wren's Nest, Dudley: Wenlock group.

Œnonites inæqualis, Hinde.

Œnonites inæqualis, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 376, pl. xviii. fig. 8.

The anterior hook is of a more blunted character, and the denticles are not so prominent as in the figured examples of this form from the Cincinnati group; but in these respects it closely agrees with the American specimens from the Clinton group, which I have referred to the same species. Length $1\frac{1}{4}$ line, width $\frac{1}{4}$ line.

Loc. and form. Ludlow: Upper Ludlow formation.

Œnonites præacutus, Hinde. (Pl. XIV. fig. 4.)

Jaw elongated, narrow; the anterior portion widest, and strongly curved inwards, the posterior extremity obliquely blunted; the anterior tooth incurved, followed by a series of acutely pointed teeth, about thirteen in number. Length $\frac{3}{4}$ line.

This form is allied to *Œ. inæqualis*, but may readily be distinguished therefrom by the incurvature of the primary tooth and the acutely pointed character of the smaller denticles.

Loc. and form. Much Wenlock: Wenlock group.

Œnonites insignificans, Hinde. (Pl. XIV. fig. 5.)

Jaw narrow, elongated, of nearly equal width throughout, slightly bent towards the posterior end; in front a single prominent tooth, followed immediately by six extremely minute denticles, which spring from the anterior third of the upper margin, the remaining portion not showing any denticles. A slightly elevated ridge borders the basal margin. Length $\frac{1}{2}$ line.

Loc. and Form. Ludlow: Upper Ludlow group.

Œnonites aspersus, Hinde. (Pl. XIV. figs. 7 & 8.)

Jaws composed of an elongated, compressed or slightly concave plate, either rounded or truncate at the posterior extremity, having in front a stout single hook, either in the same plane with or oblique to the main portion of the jaw; the upper margin nearly straight, in some instances apparently smooth, in others provided with minute crenulations or very numerous small denticles. There is considerable variation in the different examples of this abundant form; but they all appear to belong to the same species. One of the largest specimens has a length of one line, and is about $\frac{1}{4}$ line in width, whilst the smaller forms are about half this size.

Loc. and form. Much Wenlock; Wren's Nest, Dudley: Wenlock Group. Ludlow; Stoke Edith: Upper Ludlow.

Œnonites tubulatus, Hinde. (Pl. XIV. fig. 9.)

Jaw narrow, elongated and subcylindrical, basal margin undulated; the posterior extremity apparently truncate; anteriorly a relatively stout obliquely curved hook, and on the upper margin a row of minute denticles or crenulations. Length $1\frac{1}{4}$ line.

This species, in its elongated tubular form, differs considerably from any other form of these jaws. It appears to be rare, as I have found only a single specimen.

Loc. and form. Wren's Nest, Dudley: Wenlock group.

Genus Arabellites, Hinde, 1879.

Arabellites cornutus, Hinde.

Arabellites cornutus, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 377, plate xviii. figs. 13, 14, 15.

This beautiful form occurs equally well preserved in the Silurian rocks of England as in the Cambro-silurian of Canada. The only variations that can be noticed are that the anterior hook is relatively more robust, and the smaller denticles are more acutely pointed and slightly further apart from each other. There is more uniformity in the dimensions of the English specimens, which average $1\frac{1}{2}$ line in length and $\frac{1}{2}$ line in width; there are about 14 of the smaller denticles, the last three being extremely minute. It is an interesting fact that these Wenlock specimens are identical with the forms from the relatively older strata of the Cincinnati group of Canada; whilst the allied species *A. elegans*, from the contemporaneous or homotaxial Clinton group, does not appear to be represented in the Wenlock strata.

Loc. and form. Much Wenlock: Wenlock group.

Arabellites extensus, Hinde. (Pl. XIV. fig. 12.)

The main portion of the jaw formed of a relatively thick, somewhat concave plate with a prominent knuckle-shaped posterior extremity; the basal margin is curved, with a stout sharp-pointed anterior hook oblique to the main portion; the upper margin is prolonged backwards to form an extended arm on which there is a series of recurved denticles. The number of denticles altogether on the upper margin is about 15. Length $1\frac{1}{2}$ line; width $\frac{1}{2}$ line.

The tooth-bearing extension renders this species very distinct from any of the preceding. A form closely allied to, if not identical with the present species also occurs in the Cincinnati group at Toronto; but the only example I have of it is not sufficiently perfect to allow of description.

Loc. and form. Much Wenlock; Iron Bridge: Wenlock group.

Arabellites spicatus, Hinde. (Pl. XIV. fig. 13.)

Main portion of jaw subrhomboidal in form and concave, with an elongated anterior hook, the extremity of which is wanting in the specimen; the posterior extremity is hollowed out, and has an elevated spike-like projection at the corner of the base; the upper margin is nearly straight and extended backwards beyond the main portion of the jaw; there are about 10 small denticles. The reverse or inner side of the jaw shows a deep groove beneath the anterior margin, which extends to the cavity passing just below the upper hook. Length $1\frac{1}{8}$ line; width nearly $\frac{1}{2}$ line.

This form is allied to the preceding, *A. extensus*, but differs in the spike at the corner of the base, the less extension of the upper margin, and the fewer denticles.

Arabellites spicatus, var. contractus. (Pl. XIV. figs. 14 & 15.)

Jaw oblong, convex, with a relatively elongated anterior hook, not in the same plane with the anterior portion of the jaw, but obliquely curved (the point of the hook is wanting in the specimen); the posterior extremity is obliquely truncate; there are from 7 to 10 small denticles on a slightly elevated ridge, which extends in an oblique direction below the upper ridge of the jaw. On the reverse or inner side there is a deep groove traversing the jaw subcentrally, and extending to the oval aperture of the cavity below the hook. Length 1 line.

This variety differs from *A. spicatus* in wanting the extension of the upper margin, and in the different position and smaller number of the denticles.

Loc. and form. Much Wenlock: Wenlock group.

Arabellites sulcatus, Hinde.

Glycerites sulcatus, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 380, pl. xix. fig. 1.

The specimens in the Cincinnati group, from which I described this species, presented only the reverse or inner side of the jaw, and led me to suppose that it consisted merely of a simple curved hook similar to that present in the existing genus *Glycera*. I have now, however, been able to extract some of these jaws quite free from the rock matrix, and find that they possess on the front or outer surface a row of minute denticles, which would indicate that they more closely approach the genus *Arabellites*: and I therefore propose to place them under the latter genus. Examples of this form quite undistinguishable from specimens from the Cincinnati group are by no means unfrequent in the English Silurian.

Loc. and form. Much Wenlock; Wren's Nest, Dudley: Wenlock group. Ludlow: Upper Ludlow group.

Arabellites obtusus, Hinde. (Pl. XIV. fig. 16.)

Jaw subtriangular, compressed, the base straight, with a short blunted extension below; the anterior tooth curved, followed by a series of five blunted denticles. Length $\frac{1}{2}$ line.

This small form appears to be allied to *A. crenulatus*, from the Cincinnati group, from which it differs in the form and number of its denticles as well as in its smaller proportions.

Loc. and form. Much Wenlock: Wenlock group.

Arabellites anglicus, Hinde. (Pl. XIV. fig. 17.)

Jaw somewhat crescentiform, compressed, the anterior border extending obliquely downwards to form a rod-like prolongation, the posterior end truncate, a relatively stout curved anterior hook separated by an interval from the 8 blunted nearly upright denticles on the slightly arched upper margin of the jaw. Length 1 line; width $\frac{5}{8}$ line. Abundant.

This form of jaw is of the same type as *A. lunatus*, H., but differs in the projecting anterior hook, the truncated extremity, and the fewer denticles.

Loc. and form. Much Wenlock; Iron Bridge: Wenlock group. Ludlow; Stoke Edith: Upper Ludlow group.

Arabellites similis, Hinde.

Arabellites similis, Hinde, Quart. Journ. Geol. Soc. vol. xxxv pp. 382, 384, pl. xx. fig. 8.

Examples of this form, though not unfrequent, are in a poor state of preservation; so that it is difficult to determine whether they properly belong to this or the allied form *A. cristatus*. Whilst some are undoubtedly identical with *A. similis*, there are certain specimens which in their dimensions and the form of the denticles appear to be intermediate between *A. similis* and *A. cristatus*.

Loc. and form. Much Wenlock: Wenlock group. Ludlow; Stoke Edith: Upper Ludlow group.

Genus Lumbriconereites, Ehlers, 1868.

Lumbriconereites basalis, Hinde.

Lumbriconereites basalis, Hinde, Quart. Journ. Geol. Soc. vol. xxxv. p. 383, plate xix. fig. 22.

The English examples of this species do not possess the stout anterior tooth, and are of smaller dimensions than the Canadian forms; but in their general figure, number of denticles, and distinctive flange they are similar. Average length 1 line.

Loc. and form. Much Wenlock; Wren's Nest, Dudley: Wenlock group.

Genus Staurocephalites, Hinde, 1879.

Staurocephalites serrula, Hinde. (Pl. XIV. figs. 18–20.)

Jaw elongated, compressed, in some instances having the anterior border slightly incurved; generally, however, the jaw-plate is flattened and in shape like the blade of a common hand-saw; the posterior end narrowed and slightly truncate; on the upper margin a series of from 15 to 17 denticles, gradually diminishing in size towards the posterior end. The denticles are of very varying forms in different examples—either short and rounded, triangular and pointed, or needle-shaped; and they are either upright or directed backwards. In the majority of examples the anterior tooth is but slightly larger than the next following it in the series; but occasionally it is more prominent, yet similar in form and direction to the others in the same jaw. There is a great variety in the size of different examples, the smallest being only $\frac{5}{8}$ line in length, while the largest is $2\frac{1}{8}$ lines long and $\frac{5}{8}$ line wide.

This form approaches very closely to the *S. niagarensis*. H., from the Niagara formation of Canada; but it is less incurved, and generally a wider and larger speeies. It is the most abundant of any of the Annelid jaws, and occurs in all the localities of the Wenlock formation in very excellent preservation.

Loc. and form. Much Wenlock; Iron Bridge; Wren's Nest, Dudley: Wenlock group.

Genus Nereidavus, Grinnell, 1877.

Nereidavus antiquus, Hinde. (Pl. XIV. fig. 21.)

Jaw elongated, widest at the posterior extremity and gradually tapering to the anterior obliquely projecting hook; the central portion slightly concave; the basal margin curved; the nearly straight upper margin carries numerous minute crenulations. The reverse or under surface gently convex, and near the posterior end an oval aperture. Length 1 line; greatest width $\frac{1}{4}$ line.

Loc. and form. Iron Bridge, Salop: Wenlock group.

Summary.

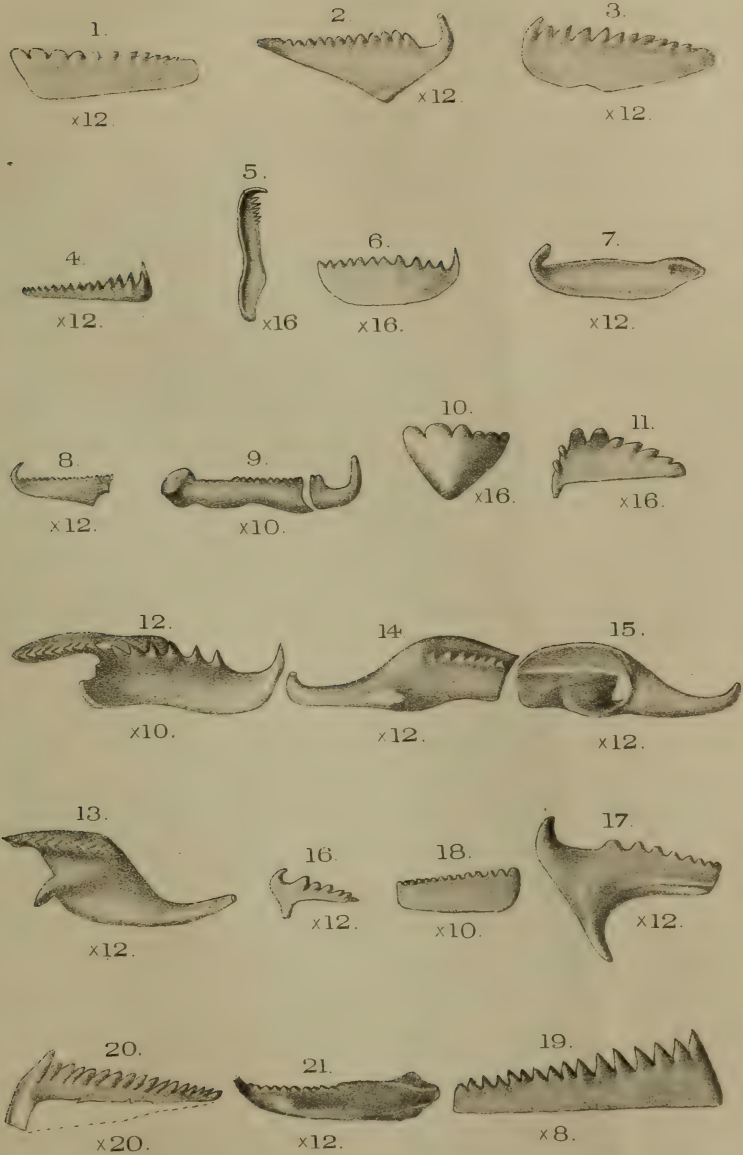
Of the 27 forms mentioned in this paper, 21 are found only in the Wenlock group; 4 are common to the Wenlock and Ludlow, and 2 are restricted to the Ludlow group. There are in the Wenlock strata 8 forms which have already been described from the American rocks; of these, 2 are met with in the Cincinnati and Clinton groups as well as the Wenlock, 3 appear in the Cincinnati and Wenlock and are absent from the Clinton, and 3 are present in the Clinton and Wenlock and not in the Cincinnati group. Two of the forms from the Ludlow group are also present in the American rocks; one of these is present in both the Cincinnati and Clinton, the other in the Cincinnati group only. The close relationship of these Annelid remains in such widely separated localities is not only shown by the number of the forms which are identical, but also by the very general resemblance which exists in those forms which are here provisionally described as new.

EXPLANATION OF PLATE XIV.

Fossil Annelid Jaws from the Wenlock and Ludlow Formations.

Fig. 1. *Eunicites curtus*, H.: × 12. Much Wenlock.
2. *Œnonites regularis*, H.: × 12. Dudley.
3. —— *naviformis*, H.: × 12. Dudley.
4. —— *præacutus*, H.: × 12. Much Wenlock.
5. —— *insignificans*, H.: × 16. Ludlow.
6. —— *cuneatus*, var. *humilis*: × 16. Iron Bridge, Salop.

Fig. 7. *Œnonites aspersus*, H.: × 12. Stoke Edith.
8. —— ——: × 12. Much Wenlock.
9. —— *tubulatus*, H.: × 10. Dudley.
10. —— *chiromorphus*, var. *minor*. × 16. Dudley.
11. —— *unguiculus*, H.: × 16. Dudley.
12. *Arabellites extensus*, H.: × 10. Iron Bridge, Salop.
13. —— *spicatus*, H.: × 12. Much Wenlock.
14, 15. —— *spicatus*, var. *contractus*: × 12. Fig. 14 represents the upper or outer, fig. 15 the under or inside of this species: ×12. Much Wenlock.
16. —— *obtusus*, H.: × 12. Much Wenlock.
17. —— *anglicus*, H. × 12. Much Wenlock.
18–20. *Staurocephalites serrula*, H. Three different examples of this species. Fig. 18, × 10; fig. 19, × 8, and fig. 20, × 20. All from Dudley.
21. *Nereidavus antiquus*, H.: × 12. Iron Bridge, Salop.



A S Foord del et lith. Mintern Bros imp.

FOSSIL ANNELID JAWS.

29. *The* Classification *of the* Tertiary Period *by means of the* Mammalia.

By W. Boyd Dawkins, M.A., F.R.S., F.G.S., Professor of Geology in Owens College. (Read April 14, 1880.)

Contents.

1. *Introduction.*

The classification of the Tertiary, or the third of the great life-periods, sketched in outline more than fifty years ago, and since then altered in no important degree, seems to me not to be in harmony with our present knowledge; and the definitions of the series of events which took place in it have been materially modified by recent discoveries in various parts of the world. The terms Eocene, Miocene, and Pliocene* no longer express the idea of percentages of living species on which they were based, and Quaternary, Post-Tertiary, and Recent are founded on an assumed great break in the life-history between the present day and the Tertiary period, comparable to that which separates the Secondary from the Tertiary or the Primary periods, a break which has been disproved by more recent inquiries. It has therefore seemed to me opportune to lay before the Society the results of the investigations which I have carried on for some years into these questions, and to propose a classification of the Tertiary period of Europe by appealing to the

* The "Miocene" and "Pliocene" of the text have been substituted for the "Meiocene" and "Pleiocene" of the author, which appear to him to agree better with their Greek roots.

Mammalia, by applying the same method by which the Pleistocene and the Prehistoric periods have already been defined*.

2. *The Value of Invertebrates and Vertebrates in Classification.*

The Eocene, Miocene, and Pliocene divisions of the Tertiary period are based upon the varying percentages of living Mollusca in a comparison of three thousand fossil with five thousand living forms; and the term Pleistocene† was subsequently invented to imply a nearer approximation to existing nature. Since that time the number of living Mollusca in the various groups has been materially altered by a wider area of observation, and it has been found impossible to map off the Pleistocene from the Pliocene on the one hand, and from the Prehistoric on the other, by their means, since by far the larger majority of the Mollusca now living in our seas date from the Pliocene age. In other words, the Mollusca have not changed with sufficient swiftness to allow of their being used to classify the later Tertiary divisions. Nor have the invertebrate faunas of Europe generally changed fast enough to mark the later Tertiary divisions. They arrived at their equilibrium towards the close of the Secondary period. The lower vertebrates also had passed through their most important biological changes before the beginning of the Tertiary, and in the Eocene age we find ourselves confronted by fishes, amphibians, and reptiles belonging, for the most part, to living genera. It is only when we appeal to the highest of all, the Placental Mammalia, that we are able to note specific changes which are sufficiently rapid for the purposes of classification. They appear in the Eocene age, as Prof. Gaudry happily terms it, "en pleine évolution"‡, and were in the same transitory condition throughout the greater part of the Tertiary that is seen in the lower animals of the Primary and Secondary periods.

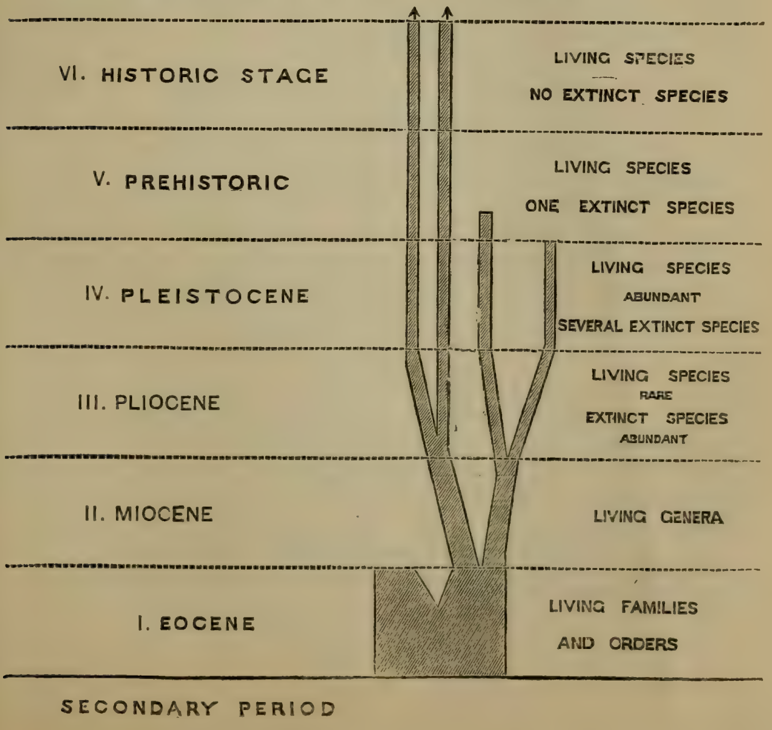
3. *The Principle of Classification.*

The fossil Mammalia of Europe, and (so far as I am able to judge from the works of Marsh, Leidy, and Cope) of America also, present stages of specialization which coincide with the geological divisions, and enable us to attach new definitions to the old names, as follows:—

* International Congress of Prehistoric Archæology. Norwich volume.
† Lyell, 'Principles,' 1st edit. iii. 1833; 'Antiquity of Man,' 1st edit. p. 3.
‡ Les Enchaînements.

	Characteristics.
VI. Historic, in which the events are recorded in History.	Historical Record.
V. Prehistoric, in which domestic animals and cultivated fruits appear.	Man abundant. Domestic animals. Cultivated fruits.
IV. Pleistocene, in which living species of Placental Mammals are more abundant than the extinct.	Man appears. Living species abundant.
III. Pliocene, in which living species of Placental Mammals appear.	Living species appear.
II. Miocene, in which the alliance between living and Placental Mammals is more close than before.	Living genera appear.
I. Eocene, in which the Placental Mammals now on the earth were represented by allied forms belonging to existing Orders and Families.	Living Orders and Families appear.

This may be represented by the following diagram:—



The orders, families, genera, and species in the above table, when traced forward in time, thus fall into the shape of a genealogical tree, with its trunk hidden in the Secondary period, and its branchlets (the living species) passing upwards from the Pliocene—a tree of life, with living mammalia for its fruit and foliage. Were the extinct species taken into account, it would be seen that they fill in the intervals separating one living form from another, and that they, too, grow more and more like the living forms as they approach nearer to the present day.

It must be remembered that in the above definitions the fossil marsupials are purposely ignored, because they began their specialization in the Secondary term, and had arrived in the Eocene at the stage which is marked by the presence of a living genus—the *Didelphys**. Each of the above groups of mammalia will be taken separately, beginning with the Eocene period.

4. *The Eocene Mammalia of Britain and France.*

The Mammalia which lived in Eocene Britain and France fall naturally into three groups—(1) the Lower or Pre-nummulitic, (2) the Middle or the Nummulitic, and (3) the Upper or Post-nummulitic. In determining the British species in the accompanying lists, I have used the works of Prof. Owen†, and have to acknowledge the valuable aid of Mr. William Davies, of the British Museum, in which collection, and in the Woodwardian at Cambridge, most of the specimens are preserved. Those of France, obtained principally from the works of Professors Gervais and Gaudry ‡, have for the most part been checked by me in the Jardin des Plantes in Paris and other French collections.

4*a*. *Principal Eocene Mammalia of Britain.*

LOWER EOCENE.

MARSUPIALIA.

Didelphys colchesteri, *Ow.* Woolwich and Reading beds, Kyson.

UNGULATA PERISSODACTYLA.

Hyracotherium leporinum, *Ow.* Woolwich and Reading beds, Kyson.
—— cuniculus, *Ow.* Woolwich and Reading beds, Kyson.
Coryphodon eocænus, *Ow.* London Clay, Harwich.
Pliolophus vulpiceps, *Ow.* London Clay, Harwich.

MID EOCENE.

UNGULATA PERISSODACTYLA.

Lophiodon minimus, *Ow.* Bracklesham.

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* =*Peratherium* of Gervais. In the view in the text, I am following Gaudry.

† 'Palæontology' and 'British Fossil Mammalia.'

‡ Gervais, 'Paléontologie Française,' 4to, 1859; Gaudry, 'Sur les Enchaînements du monde animal,' 8vo, 1878.

UPPER EOCENE.

Marsupialia.

Didelphys. Hordwell.

Carnivora (Marsupialia).

Hyænodon leptorhynchus, *Blainv.* Hordwell.

Ungulata Perissodactyla.

Anchitherium radegondense, *Gerv.* Bembridge.
Palæotherium crassum, *Cuv.* Hordwell.
—— magnum, *Cuv.* Bembridge.
—— medium, *Cuv.* Binstead.
—— minus, *Ow.* Hordwell.
Paloplotherium annectens, *Ow.* Hordwell.

Ungulata Artiodactyla non Ruminantia.

Anthracotherium. Hempstead, Bembridge.
Microchœrus erinaceus, *S. V. Wood.* Hordwell.
Chœropotamus Cuvieri, *Ow.* Isle of Wight.
Dichodon cuspidatus, *Ow.* Hordwell.
Anoplotherium commune, *Cuv.* Binstead.

Ungulata Artiodactyla Ruminantia.

Dichobune ovinum, *Ow.* Binstead.
—— cervinum, *Ow.* Binstead.

Rodentia.

Theridomys.

Primates, Lemuridæ.

Acotherulum.

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4 b. *Principal Eocene Mammalia of France.*

LOWER EOCENE=ORTHROCÈNE, *Gervais*, p. 324.

Marsupialia Carnivora.

Arctocyon primævus, *Gerv.*
Palæonictis gigantea, *Blainv.*

Ungulata Perissodactyla.

Coryphodon anthracoideum, *Ow.*

MID EOCENE=EOCÈNE, *Gervais*, p. 327.

Ungulata Perissodactyla.

Lophiodon, 10 species.
Pachynolophus, 5 species.
Propalæotherium, 2 species.

Ungulata Artiodactyla.

Anchilophus.
Heterohyus.

Ungulata Artiodactyla Ruminantia.

Dichobune.

UPPER EOCENE=PROICÈNE, *Gervais*, p. 328.

MARSUPIALIA.

Didelphys, *Cuv.*=Peratherium, *Gerv.*, 5 species.
Proviverra cayluxi, Gaudry*.
Hyænodon, 3 species.
Pterodon dasyuroides, *Blainv.*

UNGULATA PERISSODACTYLA.

Anchitherium (?) Dumasii, *Gerv.*
—— radegondense, *Gerv.*
Palæotherium, 6 species.
Paloplotherium, 2 species.
Lophiotherium cervulum, *Gerv.*

UNGULATA ARTIODACTYLA.

Anoplotherium commune, *Cuv.*
Eurytherium latipes, *Gerv.*
Chœropotamus parisiensis, *Cuv.*
Cebochœrus, 2 species.

UNGULATA ARTIODACTYLA RUMINANTIA.

Amphimœryx, 2 species.
Dichobune leporinum, *Cuv.*
Cainotherium (Hyægulus), 2 species.
Xiphodon, 3 species.

CARNIVORA (? MARSUPIALIA).

Canis (?) parisiensis †, *Cuv.*
Cynodictis lacustris, *Gerv.*
Cyotherium parisiense, *Gerv.*
Galethylax Blainvillei, *Gerv.*
Tylodon Hombresii, *Gerv.*
Amphicyon.

RODENTIA.

Plesiarctomys Gervaisii, *Brav.*
Sciurus fossilis, *Cuv.*
Theridomys, 2 species.

CHIROPTERA.

Vespertilio parisiensis ‡.

PRIMATES, LEMURIDÆ.

Adapis parisiensis, *Cuv.*
Adapis (Aphelotherium) Duvernoyi, *Gaudry.*
Acotherulum.
Tapirulus hyracinus, *Gerv.*

5. *Characteristic Forms of the Three Eocene Divisions.*

The few Lower-Eocene mammals which have been preserved present characters of great importance. Not only are the marsupials represented by a living genus, *Didelphys* (Opossum), but, as Prof. Gaudry has pointed out §, decided traces of a marsupial ancestry are to be observed in the *Arctocyon* and the *Palæonictis*—the former being allied to the bear in its dental characters and to the Marsupials in the low organization of its brain, and the latter in its teeth resembling the Tasmanian Dasyure. They show that at this time the European Carnivores were intermediate between the Marsupials and the Placental mammals.

* Les Enchaînements, c. 1.
† This Eocene genus is too imperfect to be satisfactorily defined.
‡ This Eocene genus has not been satisfactorily defined.
§ Les Enchaînements.

The presence of a living Marsupial genus in a fauna in which Placental living genera are absent might be expected, since the Marsupials lived throughout the Secondary period, while the Placental mammals only appear in the Tertiary. The former therefore in the Lower-Eocene age were in a more advanced stage of evolution than the latter.

The Tapir-like *Coryphodon* is widely distributed, and marks the horizon of the Lower Eocene, not merely in France and Britain, but in Switzerland and North America. It was pentadactyle, and possessed a brain shown by Prof. Marsh to be remarkably small.

The genus *Lophiodon* appears to be characteristic of the Mid-Eocene Mammalia of Europe.

In the Upper Eocenes the Carnivora present the same association of Marsupial with Placental characters which has been observed in the Lower Eocenes, and have not yet lost the traces of their descent from a long line of Marsupial ancestors. Among the European Ungulates the Palæothere and Anoplothere are the two most characteristic forms.

The Upper-Eocene forests of France were also haunted by representatives of the highest order of Mammalia, or the Primates, which includes the families of Man, the Ape, and the Lemur. The *Adapis** of the Paris basin, classified by Cuvier with the Anoplotheres, has recently been proved to be related to the last of these, as well as to the hoofed quadrupeds and Insectivores. To the same family also belong the *Necrolemur*†, discovered in the south of France, and the *Cænopithecus*‡ of Rütimeyer, found in Switzerland. The family is also proved§ by Marsh and Cope to have inhabited the forests of North America during the whole of the Eocene age in New Mexico, Wyoming, Dakotah, and Nebraska. None of these are identical with any living genus of Lemurs; but all possess characters bringing them into relation with one or other of the families of hoofed quadrupeds living in the Eocene period.

6. *The Miocene Mammalia.*

The Miocene Mammalia, represented in Britain by the *Hyopotamus*, are well defined by discoveries made in various parts of the

* Gervais, 'Zool. et Paléontologie Générale,' p. 28 *et seq.*; 'Journ. de Zool.' i. p. 476; 'Phosphorites de Quercy, Tarn-et-Garonne et Lot.'

† Filhol, 'Journ. de Zool. ii. p. 476; Gaudry, *op. cit.* iv. p. 21; Delfortrie, *op. cit.* ii. p. 476; Gaudry, 'Les Enchaînements,' ch. x.

‡ Rütimeyer, 'Ueber die Herkunft unserer Thierwelt' (4to, 1867), p. 52. The fauna of the Bohnerz, in which the *Cænopithecus* was found, is considered by Heer to be of Mid-Eocene age. It seems to me more probable that it represents also the Upper and Lower divisions. The local deposit of Bohnerz (iron-ore) in Switzerland had begun in the Cretaceous age, and may have been continued throughout the Eocene period. The fauna contains characteristic forms of Upper- as well as Middle-Eocene species.

§ Marsh, "Introduction and Succession of Vertebrate Life in America," American Association for the Advancement of Science, 1877; Cope, "*Hyopsodus*," Report of U.S. Geological Survey of the Territories, Fossil Vertebrates, i. p. 75.

Continent, and appear to me to fall naturally into three divisions—Lower, Middle, and Upper.

7. *The Lower-Miocene Mammalia of France.*

The animals which characterize the Lower Miocenes of France consist of the following species derived from (1) St. Gerand-le-Puy (Allier), (2) Vaumas and St. Pourcin-sur-Hètre (Allier), (3) Issoire, Volvic (Puy-de-Dôme).—*Gervais*, Zool. et Paléont. Franç. pp. 341 *et seq.*

MARSUPIALIA.

Didelphys=Peratherium (3)*.
Hyænodon leptorhynchus, *de Laiz.* (2).

UNGULATA PERISSODACTYLA.

Rhinoceros minutus, *Cuvier* (3).
Tapiris Poireri, *Pomel* (2).

UNGULATA ARTIODACTYLA.

Palæochœrus (Hyotherium) (1), (3).
Anthracotherium magnum, *Cuv.* (3).
Hyopotamus borbonicus, *Gerv.* (2).

UNGULATA ARTIODACTYLA RUMINANTIA.

Dremotherium Feignouxii, *Geoff.* (1), (3).
Amphitragulus elegans, *Pomel* (1), (3).
Cainotherium commune, *Gerv.* (1), (3).
Synaphodus brachygnathus, *Pomel* (3).

CARNIVORA.

Amphicyon gracilis, *Pomel* (1).
—— brevirostris, *Gerv.* (3).
Viverra primæva, *Pomel* (3).
—— antiqua, *Blainv.* (1).
Potamotherium Valetoni, *Gerv.* (1).
Mustela plesictis, *de Laiz.* (1).
Mustela Croizeti, *Pomel* (3).
—— elegans, *Gerv.* (1).
—— sectoria, *Gerv.* (3).
—— angustifrons, *Gerv.* (1).
—— minuta, *Gerv.* (1).

RODENTIA.

Steneofiber viciacensis, *Gerv.* (1).
Sciurus (1).
Theridomys breviceps, *Gerv.* (3).
—— Blainvillei, *Gerv.* (3).
Myoxus murinus, *Pomel* (1).
Cricetodon (3).
Titanomys visenoviensis, *Meyer* (1).

INSECTIVORA.

Erinaceus arvensis, *Blainv.* (3).
Myogale naiadum, *Pomel* (3).
Plesiosorex soricinoides, *Gerv.* (3).
Mysarachne Picteti, *Pomel* (3).
Sorex antiquus, *Pomel* (1).
Talpa acutidentata, *Blainv.* (3).
—— antiqua, *Blainv.* (3).

The Mammalia of Ronzon, Villebramar, and Le Puy-en-Velay, considered by Prof. Gaudry † to belong to a still lower horizon of the

* These numbers relate to the above localities.

† 'Les Enchaînements,' p. 5, and 'Les Animaux Fossiles de Mont Léberon,' 4to, p. 86.

Miocene than the above, will probably, as Prof. Gervais suggests, ultimately be classed with the Upper Eocene.

8. *The Characteristic Lower-Miocene Forms.*

It appears from the examination of the lists of Miocene species, which I have selected as typical, that at least twenty-three living genera appear in the Miocene age, of which the following belong to the lower division:—

Rhinoceros, *Rhinoceros.*	Hedgehog, *Erinaceus.*
Tapir, *Tapirus.*	Dormouse, *Myoxus.*
Mustela, *Mustela.*	Water-Shrew, *Myogale.*
Viverra, *Viverra.*	Mole, *Talpa.*
Squirrel, *Sciurus.*	

The genera surviving from the Eocene are:—

Didelphys.	*Anchitherium.*
Hyœnodon.	

The genus *Xiphodon* is represented by the more specialized *Amphitragulus.*

The two most characteristic genera are the hog-like *Hyopotamus* and the *Anthracotherium,* with back teeth like the hog, and with premolars, canines, and incisors as well adapted for piercing and dividing flesh as in the Carnivores. There were no true hogs, nor representatives of the family of elephants; and in a large and varied group of animals representing the deer and antelopes there were none bearing antlers or horns.

The most important fact presented by this fauna is that the opossums still lingered in the forests of Europe, and that the Marsupial ancestry of the Carnivores still asserted itself in the singular combination of characters offered by the *Hyœnodon.* With the close of the Lower Miocene age we bid farewell to the European Marsupials; and none of their characters have been observed in the Placental mammals of the Old World in any subsequent age.

9. *The Mid-Miocene Mammalia of France.*

The next well-defined horizon in the history of the Miocene mammalia of Europe is offered by the faunas of (1) Sansan, (2) Simorre, and (3) St. Gaudens, in the south of France, described by Professors Lartet, Gervais, and Gaudry, and given in the following list, in which the numbers relate to the localities.

EDENTATA.

Macrotherium giganteum, *Lart.* (1).

PROBOSCIDEA.

Mastodon angustidens, *Cuv.*
—— tapiroides, *Cuv.* (1), (2).
Dinotherium intermedium, *Kaup* (2).

Ungulata Perissodactyla.

Anchitherium aurelianense, *Gerv.* (1).
Rhinoceros brachypus, *Lart.* (2).
—— sansaniensis, *Lart.* (1).
Rhinoceros cimogorrhensis, *Lart.* (2).
Aceratherium tetradactylus, *Lart.* (2)

Ungulata Artiodactyla.

Sus chœrotherium, *Blainv.* (1).
—— lemuroides, *Blainv.* (1).
Chœromorus simplex, *Gerv.* (1).
Listriodon splendens, *Meyer* (2).
Chalicotherium grande, *Gerv.* (1).

Ungulata Artiodactyla Ruminantia.

Antilope clavata, *Gerv.* (1).
Dicroceros elegans, *Lart.* (1).
Micromeryx Flourensianus, *Lart.* (1).

Carnivora.

Hyænarctos hemicyon, *Lart.* (1).
Amphicyon * zibethoides, *Blainv.* (1).
Thalassictis (?) incerta, *Lart.* (1).
Viverra sansaniensis, *Lart.* (1).
—— exilis, *Blainv.* (1).
Felis media, *Lart.* (1).
Machairodus palmidens, *Gerv.* (1).
Pseudælurus quadridentatus, *Gerv.* (1).
Lutra dubia, *Blainv.* (1).
Mustela hydrocyon, *Lart.* (1)
—— taxodon, *Lart.* (1).
—— genettoides, *Lart.* (1).
—— zorilloides, *Lart.* (1).

Rodentia.

Castor subpyrenaicus, *Lart.* (2).
Steneofiber sansaniensis, *Gerv.* (1).
Sciurus sansaniensis, *Lart.* (1).
—— Gervaisianus, *Lart.* (1).
Myoxus sansaniensis, *Lart.* (1).
Cricetodon sansaniensis, *Lart.* (1).
—— medius, *Lart.* (1).
—— minor, *Lart.* (1).
Lagomys (Titanomys) sansaniensis, *Lart.* (1).

Insectivora.

Erinaceus sansaniensis, *Lart.* (1).
Myogale sansaniensis, *Lart.* (1).
Talpa sansaniensis, *Lart.* (1).
—— minuta, *Blainv.* (1).

Chiroptera.

Vespertilio noctuloides, *Lart.* (1).
—— murinoides, *Lart.* (1).

Primates, Simiadæ.

Pliopithecus antiquus, *Gerv.* (1).
Dryopithecus Fontani, *Lart.* (3).

10. *The Characteristic Mid-Miocene Forms.*

The new living genera are *Sus*, *Cervus*, *Antilope*, *Felis*, *Lutra*, *Castor*, the hogs being remarkable for the small size of their canines, and the deer and antelopes for their small antlers and horns. The rhinoceroses are larger in bulk than those of the Lower Miocene; and some, probably the females, are hornless. The

* Prof. Gaudry, remarks that the *Amphicyon* of the Mid-Miocene strata possesses "des réminiscences de l'état marsupial" ('Les Enchaînements,' p. 24).

genera *Anchitherium* and *Amphicyon* are among the survivors from the Upper Eocene. The Proboscidea are represented by the Deinothere and the *Mastodon*, while the Edentates are represented by a gigantic anteater, the *Macrotherium*. The genus *Machairodus* also appears for the first time, as well as the *Hyænarctos*, found also in the Miocenes of the Sevalik hills.

The higher apes also haunted the Mid-Eocene forests of France, Switzerland, Germany, and Italy. The *Pliopithecus* of Sansan is considered by Prof. Gervais * and Dr. Forsyth Major † to be allied to the anthropoid division; while a second, the *Dryopithecus* of St. Gaudens, according to Prof. Lartet ‡, rivalled man in size, and, according to Prof. Owen §, is allied to the *Pliopithecus* and to the gibbons. A third, found at Steinheim in Württemberg, is referred by Prof. Fraas ‖ to the genus *Colobus* (*Colobus grandævus*); and a fourth, *Oreopithecus*, is stated by Prof. Gervais to be allied to the anthropoid apes, the macaques, and the baboons.

Man is believed by Dr. Hamy ¶ and M. de Mortillet** to have belonged to the Mid-Miocene fauna of France, on the grounds that the splinters of flint found in the Mid-Miocene strata at Thenay by the Abbé Bourgeois††, and that the notches on a rib of *Halitherium* found at Ponancé by M. Delaunay are beyond a doubt artificial and human. The evidence, however, seems to me to be unsatisfactory. It is most unlikely that man, the most specialized of the Mammalia, formed part of a fauna in which no other living species of mammal was present. He belongs to a far more advanced stage of evolution than that of the Mid-Miocene age, as may be seen by the examination of the diagram, p. 381; and the evolution of the animal kingdom had at this time advanced as far as, but no further than, the Simiadæ.

11. *The Upper-Miocene Mammalia.*

The labours of Dr. Kaup, of Darmstadt, followed many years afterwards by the remarkable discoveries of Prof. Gaudry in Italy and France, enable us to form an adequate idea of the Mammalia living in Europe in the Upper-Miocene age. The following list is compiled principally from the work of the last-named author ‡‡.

* Zool. et Pal. Franç. p. 8.

† Atti della Soc. Ital. di Sc. Nat. xv. 1872.

‡ Comptes Rendus, xliii. 1856. The late development of the wisdom-tooth, considered by Lartet to be a character peculiar to this animal, is met with also, as Forsyth Major remarks, in the *Macacus rhesus*. It has not, therefore, the importance which is attached to it by Lartet and Lyell (Student's Elements, p. 196). See also Gaudry, 'Les Enchaînements,' p. 237.

§ Proc. Zool. Soc. Lond. xxvi. p. 18.

‖ Die Fauna von Steinheim, Württ. nat. Jahreshefte, xxvi. 1870, p. 145.

¶ Hamy, Paléontologie Humaine, p. 45.

** Mortillet, Revue Préhistorique, 1879, p. 119.

†† Bourgeois, Congr. Int. Archéol. Préhist. Paris vol. p. 67, Brussels vol. p. 81.

‡‡ Les Animaux Fossiles et la Géologie de l'Attique, 1862–68 and Les Animaux Fossiles de Mont Léberon, 4to.

	France: Vaucluse, Mont Léberon.	Spain: Concud.	Greece: Attica, Pikermi.	Hungary: Baltavar.	Germany: Hesse-Darmstadt, Eppelsheim.
EDENTATA.					
Ancylotherium pentelici, *Gaudry*	...	...	*		
Macrotherium	...	...	...	...	*
PROBOSCIDEA.					
Mastodon pentelici, *Gaudry & Lartet*	...	*	*		
Mastodon turicensis, *Schinz*	...	...	*		
—— longirostris, *Kaup*	...	...	...	...	*
Dinotherium giganteum, *Kaup*	*	...	*	*	*
PERISSODACTYLA.					
Rhinoceros pachygnathus, *Wagner*	...	...	*		
—— Schleiermacheri, *Kaup*	*	...	*	...	*
Aceratherium	*	...	*	...	*
Leptodon græcus, *Gaudry*	...	...	*		
Hipparion gracile, *Christol*	*	*	*	*	*
Tapirus	...	...	...	...	*
ARTIODACTYLA.					
Chalicotherium	*	...	...	...	*
Sus erymanthius .... } *Kaup* —— major, *Gerv.*, = var. }	*	...	*	*	
—— palæochœrus, *Kaup*	...	...	...	...	*
—— antediluvianus, *Kaup*	...	...	...	...	*
—— antiquus, *Kaup*	...	...	...	...	*
RUMINANTIA.					
Camelopardalis attica, *Gaudry & Lartet*	...	...	*		
Helladotherium Duvernoyi, *Gaudry*	*	...	*	*	
Palæotragus Rouenii, *Gaudry*	...	...	*		
Palæoryx Pallasii, *Gaudry*	...	...	*		
Tragoceros amaltheus, *Gaudry*	*	*	*	*	
Tragoceros Valenciennesi, *Gaudry*	...	...	*		
Palæoreas Lindermayeri, *Gaudry*	...	...	*		
Antedorcas (?) Rothii, *Gaudry*	...	...	*		
Gazella brevicornis, *Gaudry*	...	*	*	*	
—— deperdita, *Gaudry*	*	*	*	*	
Dremotherium pentelici, *Gaudry*	...	...	*	...	*
Dorcatherium	...	...	...	...	*
Cervus Matheroni, *Gerv.*	*				
—— anoceros, *Kaup*	...	...	...	...	*
—— dicranoceros, *Kaup*	...	...	...	...	*
CARNIVORA.					
Simocyon diaphorus, *Gaudry*	...	...	*	...	*
Mustela pentelici, *Gaudry*	...	...	*		
Promephitis Lartetii, *Gaudry*	...	...	*		
Ictitherium robustum, *Gaudry*	...	...	*		
—— hipparionum, *Wagner*	*	...	*		
—— Orbignii, *Wagner*	*(?)	...	*		
Hyæna eximia, *Roth & Wagner*	*	*	*		
—— chœretis, *Gaudry & Lartet*	...	...	*		
Hyænictis græca, *Gaudry*	...	...	*	*	
Machairodus cultridens, *Kaup.*	*	...	*	*	*
Felis attica, *Gaudry*	...	...	*		
RODENTIA.					
Hystrix primigenia, *Gaudry*	...	...	*		
PRIMATES, SIMIADÆ.					
Mesopithecus pentelici, *Wagner*	...	...	*		
Dryopithecus (?)	...	...	...	...	*

12. *The Characteristic Upper-Miocene Forms.*

The new living genera of the Upper Miocene are:—

Giraffe, *Camelopardalis*. Hyæna, *Hyæna*.
Gazelle, *Gazella*. Porcupine, *Hystrix*.

And the extinct genera surviving from the Mid Miocene are:—

Macrotherium. *Aceratherium*.
Mastodon. *Chalicotherium*.
Dinotherium. *Machairodus*.

The Edentates still lived in Germany and Greece; and the *Hipparion* was abundant in Middle and Southern Europe.

The horns of the rhinoceros and of the antelopes are larger than in the Mid-Miocene age; and the antlers of the deer, still small, are considerably larger than before, arriving at their maximum development in the *Cervus Matheroni*, Gerv., of Mont Léberon *. The canines of the hogs still remained very small.

Numerous apes intermediate between *Semnopithecus* and *Macacus* lived in the wooded slopes leading from Pikermi towards the plain of Marathon and down to the great plains, now submerged, which extended southwards towards Africa and eastwards towards Asia Minor. A large ape found at Eppelsheim extends the range of the Simiadæ as far north as lat. 49° 43′ or 14° beyond the present northern limit of the Old-World apes. It is worthy of remark that in the New World the *Laopithecus*, Marsh, of the Miocene strata of Nebraska is found from 14° to 15° north of the present range of the American Monkeys. From this it may be inferred that the climatal change by which the Simiadæ have been restricted to their present habitats, has been the same in the New and the Old Worlds.

13. *The Lower-Pliocene Mammalia of France.*

The history of the Pliocene Mammalia of Europe may be studied most conveniently from the points of view offered by the groups of animals discovered at Montpellier, and at Mont Perrier and Issoire in Auvergne, belonging to the upper and lower divisions, and those of the upper Val d'Arno in Italy, belonging to the former. The following lists are founded on those of Professor Gervais, with the addition of certain species identified by Dr. Falconer and myself.

LOWER-PLIOCENE MAMMALS OF FRANCE—STAGE OF MONTPELLIER.

PROBOSCIDEA.

Mastodon arvernensis, *Falc.*,= M. brevirostris, *Gerv.*

UNGULATA PERISSODACTYLA.

Rhinoceros megarhinus, *Christol*, = Tapirus minor, *Serres*.

UNGULATA ARTIODACTYLA.

Sus provincialis, *Gerv.*

* Dawkins, Quart. Journ. Geol. Soc. vol. xiv. p. 402.

UNGULATA ARTIODACTYLA RUMINANTIA.

Antilope Cordieri, *Christ.*
Cervus cusanus, *Cr. et Job.*
—— australis, *Serres.*

CARNIVORA.

Ursus minutus, *Gerv.* (? Ursus arvensis, *Cr. et Job.*)
Hyænarctos insignis, *Gerv.*
Felis Christolii, *Gerv.*
Lutra affinis, *Gerv.*

RODENTIA.

Chalicomys sigmodus, *Gerv.*
Lagomys loxodus, *Gerv.*

PRIMATES, SIMIADÆ.

Semnopithecus monspessulanus, *Gerv.*
Macacus priscus, *Gerv.*

This group of animals presents no living species of Mammalia, and it is only classed with the Pliocene because of the presence of well-defined Upper-Pliocene species, such as *Mastodon arvernensis*, *Rhinoceros megarhinus*, *Ursus arvernensis*, and *Cervus cusanus*. The extinct genera *Hyænarctos*, *Mastodon*, and *Hipparion* survived from the Miocene; and the two apes belong to the living genera, *Macacus* and *Semnopithecus*. None of the deer possess large antlers; nor have the hogs large canines.

14. *The Upper-Pliocene Mammalia of France and Italy.*

The Upper-Pliocene mammals of France and Italy are represented by the following groups, of which the one has been defined by MM. Croizet and Jobert * and Prof. Gervais †, and the other by Dr. Forsyth Major ‡.

UPPER-PLIOCENE MAMMALIA OF FRANCE—OF MONT PERRIER AND ISSOIRE.

PROBOSCIDEA.

Mastodon arvernensis, *Cr. et Job.*
Elephas meridionalis (of Malbattu), *Nesti.*

UNGULATA PERISSODACTYLA.

Rhinoceros (elatus ?)
Tapirus arvernensis, *Cr. et Job.*
Hipparion gracile (of Malbattu), *Kaup.*

UNGULATA ARTIODACTYLA.

Sus arvernensis, *Cr. et Job.*

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* Recherches sur les Oss. Foss. du Département du Puy-de-Dôme: 4to, 1828.
† Zool. et Pal. Franç. p. 349.
‡ Soc. Ital. di Antrop. et di Etnol. April 20, 1876, p. 10.

UNGULATA ARTIODACTYLA RUMINANTIA.

Bos elatus, *Croiz.*
Cervus polycladus, *Gerv.*
(=C. ramosus, *Cr. et Job.*)
—— ardens, *Cr. et Job.*
—— cladocerus, *Pomel.*
—— perrieri, *Cr. et Job.*
(=C. issiodorensis.)
Cervus etueriarum, *Cr. et Job.*
—— pardinensis, *Cr. et Job.*
—— arvernensis, *Cr. et Job.*
—— cusanus, *Cr. et Job.*
—— tetraceros, *Dawk.**
—— cylindroceros, *Dawk.**
—— polignacus, *Robert.*

CARNIVORA.

Ursus arvernensis, *Cr. et Job.*
Canis borbonicus, *Brav.*
Felis pardinensis, *Cr. et Job.*
—— arvernensis, *Cr. et Job.*
—— brevirostris, *Cr. et Job.*
Felis issiodorensis, *Cr. et Job.*
Machairodus cultridens, *Gerv.*
Hyæna arvernensis, *Cr. et Job.*
—— perrieri, *Cr. et Job.*
Lutra Bravardi, *Pomel.*

RODENTIA.

Hystrix refossa, *Gerv.*
Castor issiodorensis, *Croizet.*
Arctomys antiqua, *Pomel.*
Arvicola robustus, *Pomel.*
Lepus Lacosti, *Pomel.*

UPPER-PLIOCENE MAMMALIA OF ITALY—OF THE UPPER VAL D'ARNO.

PROBOSCIDEA.

Mastodon arvernensis, *Cr. et Job.*
Elephas meridionalis, *Nesti.*

UNGULATA PERISSODACTYLA.

Rhinoceros etruscus, *Falc.*
—— megarhinus, *Falc.*†
Equus Stenonis, *Cocchi.*

UNGULATA ARTIODACTYLA.

Hippopotamus major, *Cuv.*
Sus Strozzi, *Meneg.*

UNGULATA ARTIODACTYLA RUMINANTIA.

Bos etruscus, *Falc.*
Cervus ctenoides, *Nesti (MSS.).*
—— perrieri, *Cr. et Job.* ‡
Cervus dicranios, *Nesti.*
—— etueriarum, *Cr. et Job.* §

CARNIVORA.

Canis etruscus, *Major.*
Ursus etruscus, *Cuv.*
Hyæna perrieri, *Cr. et Job.*
Felis.
Canis Falconeri, *Major.*
Mustela.
Machairodus (3 sp.).

RODENTIA.

Castor plicidens, *Major.*
—— rosiniæ, *Major.*
Hystrix.
Lepus.

PRIMATES, SIMIADÆ.

Macacus (Aulaxinus) florentinus.
——, sp., *Cocchi.*

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* Dawkins, Q. J. G. S. xxxiv. p. 402.

† Determined by Dr. Falconer.

‡ Determined by myself in the Museum of the University of Florence.

§ Determined by myself in the Geological Museum of the University of Bologna and in the Castello Valentino, Turin, where there are also specimens of *Machairodus latidens*, Ow., and *M. cultridens*, Kaup.

15. *The Characteristic Upper-Pliocene Forms.*

The study of the Upper-Pliocene Mammalia presents the following important characteristics. The *Hippopotamus amphibius* was widely distributed through the forests of France and Italy; and numerous deer of the section Axeidæ are probably identical specifically with the deer of Southern and Eastern Asia, of the types of *Axis*, *Rusa*, and *Cervus taivanus* *. *Hipparion* appears for the last time; and with the extinction of *Macacus florentinus* the family of apes passed away from among the European fauna. The disappearance of the apes from Europe at the close of the Pliocene age is one of the most important facts in the history of the fossil mammals. In the Upper Miocene they ranged as far north as Eppelsheim. In the Lower Pliocene they were restricted to the forests of the south of France, and in the Upper Pliocene to those of Italy. Their southern retreat and final extermination in Europe are probably due to a climatal change, to a lowering of the temperature, which arrived at its minimum in the Pleistocene age.

The evidence as to the presence of man in the Italian Pliocenes, brought forward by Dr. Cocchi † and Prof. Capellini ‡, seems to me to be unsatisfactory. The Pliocene Mammalia are not sufficiently specialized, do not contain a sufficient number of living species, to make it probable that man belonged to the Pliocene fauna.

The four most important new living genera are the oxen, the horses, the bears, and the elephants. The first of these, *Bos etruscus*, was sometimes without horns, as in a skull pointed out to me in 1877 by Dr. Forsyth Major in the museum at Florence. This interesting specimen renders it likely that horns were originally a sexual character peculiar to the bulls, transferred afterwards to the cows. The cows, however, possessed horns in the succeeding Pleistocene age, in the deposits of which fossil polled cattle are unknown. If this view of the origin of horns be accepted, it is easy to explain the singular ease with which the horns have been bred out of some of the domestic cattle, in a comparatively short time, by selection carried on through a few generations, and our polled cattle may be looked upon as a reversion to an ancestral type. The small size also of the tusks of the domestic hogs, as compared with those of the wild boar, may be explained in the same manner.

The horses inhabiting the Val d'Arno in the Upper-Pliocene age were intermediate in the structure of their feet and teeth between the common horse and the *Hipparion*, and may perhaps indicate that the deposits in which they occur are later than those of Auvergne with the remains of *Hipparion*. The elephants are represented by the *Elephas meridionalis* of the Upper Pliocene of France and Italy. The bears are small, and with the canine teeth not so large as in the Pleistocene *Ursus arctos* and *U. spelæus*.

* Dawkins, Quart. Journ. Geol. Soc. vol. xxxiv. p. 402.
† Mem. della Soc. Ital. di Sc. Nat. ii. no. 7, 1867.
‡ Atti della Reale Accad. dei Lincei, ser. 2, tom. iii. 1876.

16. *The Development of Antlers in the Deer.*

The Pliocene deer occupied a position intermediate between those of the preceding and succeeding ages in regard to their development of antlers. In the Lower Miocene none of the Cervidæ were antlered. In the Mid Miocene the antlers bore simple forked crowns; and in the Upper Miocene they become more complex, but are still small and erect, like those of the roe. In the Upper Pliocene they are larger and longer, and altogether more complex than they were before, some forms, such as the *Cervus dicranios* of Nesti, being the most complicated antlers at present known. The development of antlers reaches a maximum in the Irish elk of the Pleistocene and Prehistoric ages. These successive changes are like those which take place in the development of the antlers in the living deer, which begin with a simple point and increase in size and in the number of tynes up to their limit of growth. It is worthy of remark that in the Mid-Miocene strata of Thenay small erect branching antlers, without a burr or rose and persistent through life, represent an intermediate form between the deer and the antelopes. Similar antlers to these have been figured and described by Professors Leidy and Cope from the Upper Miocenes or Lower Pliocenes of the United States.

The Pliocene Mammalia of the Coralline, Red, and Norwich Crags are so imperfectly known, so fragmentary, and so mingled with Miocene fossils while they were exposed to the dash of the waves on the Pliocene shore, that it is better not to attempt to give a systematic list of those occurring in Britain.

17. *The Pleistocene Mammalia.*

We come now to that period in the history of life when the existing species of Mammalia preponderate greatly over the extinct, to the Pleistocene age, in which the living species stand to the extinct in the relation of fifty-six to twenty-two, out of a total of seventy-eight. They fall naturally into three divisions, as I have already pointed out in previous communications to the Society:—the Early-Pleistocene, or that of the Forest-bed group; the Mid-Pleistocene, or that of the Brick-earths of the lower Thames; and the Late-Pleistocene, or those of most of the river-deposits and most of the caves *.

18. *The Early-Pleistocene Mammalia of Britain.*

The Early-Pleistocene Mammalia from the Forest-bed of Norfolk and Suffolk, given in the following list, are remarkable for the association of Pliocene species with living and extinct species before unknown. It will be remarked that the whole of the new living species are now to be found in the temperate regions.

* Quart. Journ. Geol. Soc. vol. xxviii. p. 410, xxiii. p. 91.

Survival from Pliocene—Living species = 1.

Hippopotamus..................*Hippopotamus amphibius.*

Survivals from Pliocene—Extinct species = 7.

Southern elephant ....*Elephas meridionalis*, Nesti.
Big-nosed rhinoceros ....*Rhinoceros megarhinus*, Christol
Etruscan rhinoceros ....*R. etruscus*, Falc.
Sedgwick's deer ....*Cervus dicranios* = *C. Sedgwickii*.
Deer of Polignac ....*C. polignacus*, Robert.
Sabre-toothed lion ....*Machairodus latidens* ?, Ow.
Bear of Auvergne* ....*Ursus arvernensis*, Cr. & Job.

New comers—Living species = 15.

Horse ....*Equus caballus*, L.
Wild boar ....*Sus scrofa*, L.
Urus..............................*Bos primigenius*, Boj.
Roe ....*Cervus capreolus*, L.
Stag ....*C. elaphus*, L.
Fox ....*Canis vulpes*, L.
Wolf ....*C. lupus*. L.
Squirrel ....*Sciurus vulgaris*, L.
Beaver ....*Castor fiber*, L.
Red field-vole..................*Arvicola glareolus*, Schreb.
Water-vole ....*A. amphibius*, L.
Mole ....*Talpa europæa*, L.
Common shrew ....*Sorex vulgaris*, L.
Musk shrew ....*S. moschatus.*
Glutton ....*Gulo luscus*, L. †

New comers—Extinct species = 7.

Straight-tusked elephant ...*Elephas antiquus*, Falc.
Mammoth ....*E. primigenius*, Blum.
Irish elk ....*Megaceros hibernicus*, Owen.
Thick-antlered deer ....*Cervus verticornis*, Dawk.
Deer of the Carnutes.........*C. carnutorum.*
Cave-bear ....*Ursus spelæus*, Goldf.
Extinct beaver ....*Trogontherium Cuvieri*, Owen.

Elephas meridionalis, *Rhinoceros etruscus*, *Cervus dicranios*, and *C. polignacus* appear for the last time in the Early Pleistocene, in association with the new species. Among the latter, *Elephas antiquus*, *E. primigenius*, *Ursus spelæus*, and *Trogontherium* are the most important of the extinct species.

The recent identification of the Mammoth by Prof. Leith Adams ‡, in the fauna of the Forest-bed, confirms the truth of the views of Dr. Falconer and myself §, based on other evidence, which have been doubted by some very competent observers.

19. *The Magnitude of the Break between the Plio- and Pleistocene Periods.*

An analysis of the above list shows that the break in the succession between the Pliocene and Pleistocene ages is very great, more

* It is very probable that the smaller Bear of the Forest-bed may be *Ursus ferox*, as Mr. E. T. Newton suggests.

† Identified by Mr. E. T. Newton.

‡ In a letter to the author.

§ Quart. Journ. Geol. Soc. vol. xxxv. p. 138.

than two thirds of the species being new. The proportion, however, of the Pliocene survivals to them being eight as compared with twenty-two, shows that it is not sufficiently great to allow of a classification in which the Tertiary ends with the Pliocene. It is simply a new and more advanced phase of the Tertiary, similar in kind to those which went before and follow after. If we turn our attention to the Invertebrates, there is no break at all to be observed between the Pliocene and Pleistocene, all the Pleistocene forms being found in Pliocene strata, and the same continuity being presented as that which we shall note presently in the Vertebrates of the Pleistocene, Prehistoric, and Historic periods. It is therefore obvious that the Tertiary life-period cannot in any sense be viewed as having come to an end at the close of the Pliocene age.

20. *The Mid-Pleistocene Mammalia of Britain.*

The fluviatile deposits of Ilford and Grays Thurrock in Essex, at Erith and Crayford in Kent, and at Clacton on the Essex coast, present us with a group of animals intermediate between those of the Early and Late Pleistocene. Their most important characters are noted in the following list (p. 398), in which it will be seen that *Rhinoceros megarhinus* and the *Hippopotamus* are the only two Pliocene species in the fauna; the latter appears here for the last time. It must also be remarked that *Ovibos moschatus*, discovered by myself in 1857, and more recently by Mr. Cheadle, and the Marmot, discovered recently by Mr. Flaxman Spurrell at Crayford, show that the winter cold was severe, and that the arctic Mammalia in their journey southwards had arrived as far as the lower valley of the Thames.

The climate at this time was colder than it ever had been before in Britain, and was gradually passing into the glacial condition. It is very likely, as I have pointed out in my paper on the Lower Brick-earths of the Thames valley*, that the upper strata covering the fluviatile deposits with the fossil remains are glacial, and that therefore the deposits beneath are referable to the Preglacial age.

Man is proved to have lived in the valley of the Thames at this time by a flint flake, discovered by the Rev. Osmond Fisher, in my presence, at Crayford in 1872 †, and by a second, found at Erith by Messrs. Cheadle and Woodward in 1876 ‡, and, lastly, by a recent discovery of the relics of a palæolithic factory at Crayford (shortly to be described by Mr. Flaxman Spurrell).

With the exception of the marmot and the musk-sheep, the whole of the living species consist of animals now found only in temperate or warm climates. Horses, uri, bisons, and mammoths were the most abundant animals.

* Quart. Journ. Geol. Soc. vol. xxiii. p. 91. † Geol. Mag. 1872, p. 268

‡ Proc. W. Lond. Scient. Assoc., Sept. 1876.

Mid-Pleistocene Mammalia.		Ilford.	Grays Thurrock.	Crayford, Erith.
Survivals from Early Pleistocene—Living species=11.				
Horse	*Equus caballus*, L.	*	*	*
Urus	*Bos primigenius*, Boj.	*	*	*
Roe	*Cervus capreolus*, L.	*	*	
Stag	*C. elaphus*, L.	*	*	*
Hipppotamus	*Hippopotamus major*	*	*	
Wild boar	*Sus scrofa*, L.	...	*	
Fox	*Canis vulpes*, L.	*	*	
Wolf	*C. lupus*, L.	*	*	*
Brown bear	*Ursus arctos*, L.	*	*	*
Beaver	*Castor fiber*, L.	*	*	
Water-rat	*Arvicola amphibius*, L.	*	*	*
Survivals from Early Pleistocene—Extinct species=4.				
Straight-tusked elephant	*Elephas antiquus*, Falc.	*	*	*
Mammoth	*E. primigenius*, Blum.	*	*	*
Big-nosed rhinoceros	*Rhinoceros megarhinus*, Christol.	*	*	*
Irish elk	*Megaceros hibernicus*, Ow.	*	*	*
New comers—Living species=9.				
Musk-sheep	*Ovibos moschatus*, Desm.	...	...	*
Bison	*Bison priscus*	*	*	*
Grisly bear †	*Ursus ferox*, Lew. & Clark	*	*	*
Otter	*Lutra vulgaris*, Erxl.	...	*	
Spotted hyæna	*Hyæna crocuta*, Zimm.	...	*	*
Wild cat	*Felis catus*, L.	...	*	
Lion	*F. leo*, L.	*	*	*
Marmot	*Spermophilus*	...	...	*
Man		...	...	*
New comers—Extinct species=2.				
Woolly rhinoceros	*R. tichorhinus*, Cuv.	*	...	*
Small-nosed rhinoceros	*R. leptorhinus*, Ow. (= *R. hemitœchus*, Falc.)	*	*	*

21. *The Late-Pleistocene Mammalia of Britain.*

It is unnecessary to discuss at any length the characters of the Late-Pleistocene Mammalia of the caves and river-deposits, as they have already been brought before the Society in previous communications ‡. The arctic Mammalia were present in Britain; and vast herds of reindeer, such as those found in the river-deposits at Windsor, and more recently at Rugby, and in the limestone fissure at Windy Knoll, near Castleton, in Derbyshire, swung to and fro, according to the season, over Pleistocene Europe, as far south as the Alps and the Pyrenees. The living species preponderated

† This may ultimately be proved to be a survival from the Early Pleistocene.
‡ Quart. Journ. Geol. Soc. vol. xxviii. p. 410, xxxiii. pp. 607 & 724, xxxv. p. 724.

greatly over the extinct, standing to them in the relation of forty to seven. The primæval hunter is represented by the implements left behind in the river-deposits and in the caves, belonging to two stages of culture. The earlier and ruder is, 1, that of the river-drift man, as he is termed by Mr. Evans †, whose rough stone *hâches* lie scattered over England south of Peterborough, the whole of France, Spain, Italy, and Greece, North Africa and Palestine, and have been shown by recent researches to occur over the greater part of India; the later, 2, that of the cave-man, whose implements are of a higher order and have a different distribution, being restricted to that portion of Europe bounded to the south by the Alps and the Pyrenees, to the north by Yorkshire, to the west by the ancient coast-line of the Atlantic, and to the east by Poland and the Lower Danube. It is, in my opinion, probable that these implements belong to different races, of which the latter is very likely to be identical with the modern Eskimos. They are proved by the discoveries at Hoxne, Bedford, and in the Pont-Newydd Cave, to have lived in Britain after the deposit of Boulder-clay in those districts; but they are very likely to have arrived in Europe along with the other living species of animals in pre-Glacial times. The Glacial period was not, as I have proved in a previous communication to the Society‡, a hard and fast line dividing one fauna from another. It was merely an episode in the Pleistocene age, during which the climate was exceedingly severe in Northern Europe, and during which the arctic species ranged as far south as the Alps and Pyrenees, their northern pastures being either covered by snow and ice, or submerged beneath the waves of the sea.

Late-Pleistocene Mammalia in Britain.		River strata.	Ossiferous caverns.
Survivals from Early and Mid Pleistocene — Living species=24.			
Horse	*Equus caballus*, L.	*	*
Brown's fallow-deer	*Cervus Browni*, Dawk.	*	
Roe	*C. capreolus*, L.	*	*
Stag	*C. elaphus*, L.	*	*
Urus	*Bos primigenius*, Boj.	*	
Bison	*Bison europæus*, Gm.	*	*
Musk-sheep	*Ovibos moschatus*, Desm.	*	
Hippopotamus	*Hippopotamus amphibius*, L.	*	*
Wild boar	*Sus scrofa*, L.	*	*
Wild cat	*Felis catus*, L.	*	*
Lion	*F. leo*, L.	*	*
Spotted hyæna	*Hyæna crocuta*, Zim.	*	*
Wolf	*Canis lupus*, L.	*	*
Fox	*C. vulpes*, L.	*	*
Otter	*Lutra vulgaris*. Erxl.	*	*

† 'Ancient Stone Implements.' ‡ Quart. Journ. Geol. Soc. vol. xxxv. p. 724.

Late-Pleistocene Mammalia in Britain (*continued*).		River strata.	Ossiferous caverns.
Grisly bear	*Ursus ferox*, Lew. & Cl.	*	*
Glutton	*Gulo luscus*, L.	*	*
Water-vole	*Arvicola amphibius*, L.	*	*
Red field-vole	*A. glareolus*, Schreb.	*	*
Hare	*Lepus timidus*, L.	*	*
Beaver	*Castor fiber*, L.	*	*
Mouse	*Mus musculus*, L.	*	*
Shrew	*Sorex vulgaris*, L.	...	*
Man		*	*
Survivals from Early and Mid-Pleistocene — Extinct species = 7.			
Straight-tusked elephant	*Elephas antiquus*, Falc.	*	*
Mammoth	*E. primigenius*, Blum.	*	*
Woolly rhinoceros	*Rhinoceros tichorhinus*, Cuv.	*	*
Small-nosed rhinoceros	*R. leptorhinus*, Ow. †	*	*
Irish elk	*Megaceros hibernicus*, Ow.	*	*
Machairodus	*Machairodus latidens*, Ow.	...	*
Cave-bear	*Ursus spelæus*, Goldf.	...	*
New forms—Living species = 15.			
Reindeer	*Cervus tarandus*, L.	*	*
Arctic fox ‡	*Canis lagopus*, L.	...	*
Badger	*Meles taxus*, L.	...	*
Stoat	*Mustela erminea*, L.	...	*
Weasel	*M. putorius*, L.	...	*
Marten	*M. martes*, L.	...	*
Caffer cat	*Felis caffer*, Desm.	...	*
Leopard	*F. pardus*, L.	...	*
Lynx	*F. lynx*, Tem.	...	*
Short-tailed field-vole	*Arvicola agrestis*, L.	...	*
Continental field-vole	*A. arvalis*, L.	...	*
Russian vole	*A. ratticeps*, Keys. u. Bl.	*	*
Pouched marmot	*Spermophilus citillus*, Pall.	*	*
Arctic lemming	*Mus lemmus*, L.	*	*
Norwegian lemming	*Myodes torquatus*, Pal.	...	*

22. *The Prehistoric Mammalia of Britain and Ireland.*

The Prehistoric Period, as I have defined it in a paper read before the International Congress of Prehistoric Archæology, in Paris and in Norwich, is the next phase of the Tertiary which we have to examine. It covers all the events which took place between the Pleistocene age on the one hand, and the beginning of history on the other. To it belong most of the alluvia and peat-bogs and beaches, usually termed Recent, as well as the contents of certain

† = *R. hemitœchus*, Falc.
‡ Identified by Prof. Busk among the remains found in the Pin-hole, Cresswell.

caverns containing the remains of wild animals now living in Europe, mingled with wild or half-wild animals which had escaped from their servitude to man. The principal species are given in the following list:—

		Britain.	Ireland.
Wild animals.			
Beaver		*	
Hare		*	
Alpine hare		*	*
Rabbit		*	*
Water-rat		*	
Wild cat		*	*
Otter		*	*
Marten		*	*
Badger		*	*
Brown bear		*	*
Grisly bear		?	*
Wolf		*	*
Fox		*	*
Horse		*	*
Roe		*	
Stag		*	*
Elk		*	
Irish elk		*	*
Reindeer		*	*
Urus		*	
Wild boar		*	*
Domestic animals.			
Dog	*Canis familiaris*, L.	*	*
Horse	*Equus caballus*, L.	*	*
Sheep	*Ovis aries*, L.	*	*
Goat	*Capra hircus*, L.	*	*
Shorthorn	*Bos longifrons*, Ow.	*	*
Hog	*Sus scrofa*, L.	*	*
Marsh-hog	*S. palustris*, Rüt.		

23. *The Characteristic Prehistoric Forms.*

The most important feature of the Prehistoric period is the arrival of a race of men totally distinct from those of the Pleistocene, and in a far higher state of culture. The Neolithic farmer and herdsman first of all appears, bringing with him the domestic animals of the above list, and some of the cultivated seeds. Subsequently bronze became known, and then iron, each of these substances standing for an outward sign of a civilization better than that which had preceded it. Thus we have the Neolithic succeeded by the Bronze age, and that by the Iron,—the history of Britain beginning late in the last of these three divisions.

Among the wild animals the Irish elk demands especial notice, not merely from its existence in vast numbers in Ireland, but from the fact that it is the sole survivor from the Pleistocene into the Prehistoric age which has since become extinct. It is rarely met with in Britain. The true elk was also rare, but has been met with in several localities in the bogs of Northumberland, Yorkshire, and Scotland. In the south it is described by Prof. Owen from Walthamstow, where it was associated with the goat, Celtic shorthorn, and reindeer. The last animal is rare in England, and comparatively abundant in Scotland and Ireland. It has not been found in Prehistoric deposits further south than the valley of the Thames. The Urus was comparatively abundant in Prehistoric Britain, and it was hunted by the Neolithic men who excavated the chalk for the sake of the flint in Cissbury Camp. It survived at least as late as the Bronze age, since its remains occur in a refuse-heap of that age in Barton Mere, near Bury St. Edmunds *. It was probably exterminated in Britain before the close of the Prehistoric period, while it found a secure shelter from man in the forests covering Central Germany as late as the sixteenth century.

The domestic animals introduced by the Neolithic farmers consist of the dog, horned sheep, goat, Celtic short-horned ox, and hog, some of which, such as the short-horned ox, the marsh-hog, and the goat, escaped from the servitude of man, and reverted to a wild state in the forests as yet untouched by the woodman's axe. The domestic horse also may have been introduced in a state of domestication; but it may have been descended from those so abundant in Britain in the Pleistocene age.

24. *The Historic Mammalia of the British Isles.*

It remains for us to consider, in conclusion, the more important changes in the fauna of the Historic period, or that period of which the written record is preserved, and which may be said to begin in Britain with the landing of Julius Cæsar, B.C. 55. The chief points to be noted are the absence of the Irish elk and of the true elk and urus from the British fauna. The reindeer still lingered in the north of Scotland, and was used for food by the dwellers in the burgs of Caithness, in which district it was hunted by the Earls of Orkney in the year 1159. The extinction of some and the introduction of other animals into Britain enable us to divide the Historic period in the same manner as the preceding divisions of the Tertiary have been made; and the following Table, taken from my work on Cave-hunting, gives an outline of the principal of these changes †.

* Proc. of Suffolk Inst. of Archæol. and Nat. Hist. June 1869.

† The authorities for these facts and dates are given in my 'Preliminary Treatise, British Pleistocene Mammalia,' Palæontological Society, 1878, chapters ii. and iii.

Animals extinct:—

		A.D.
Brown bear	circa	500–1000.
Reindeer	„	1200.
Beaver	„	1100–1200.
Wolf	„	1680.
Wild boar	„	1620.

Animals introduced:—

Domestic Fowl	before	55 B.C.
Fallow deer	circa	50–100 A.D.
Pheasant	„	50–100 A.D.
Domestic ox of *Urus* type	„	449 A.D.
Ass	„	800–850 A.D.
Cat	„	800–1000 A.D.
Common rat	„	1727–1730 A.D.

25. *The Prehistoric and Historic Periods belong to the Tertiary.*

If the list of Prehistoric Mammalia be compared with that of the late Pleistocene, it will be seen that great differences are to be observed. No less than seventeen Pleistocene species have disappeared from Britain in the interval separating the one from the other, some having become extinct, others having retreated to the north or to the south, or to the shelter offered by the forests of Central Europe, or to the cold climate of lofty mountains. It must, however, be remembered that all the wild Prehistoric animals were living in the preceding age, and that from the Pleistocene age down to the present time the wild fauna and flora of Europe have been what they are now. The continuity has been unbroken. It is therefore evident that the Tertiary period must be extended so as to include the events of our own times.

26. *General Conclusions.*

From this imperfect outline of the groups of Placental mammals living in Europe in successive times, it is obvious that they present us with a means of classifying the Tertiary period with greater detail and certainty than those of the lower animals. The groups chosen as typical are those which seem to me to be the most important; but it must be noted that their apparent isolation is merely the measure of the imperfection of our knowledge and of the geological record. They show that in the Tertiary period the Placental mammals were gradually becoming more specialized and more like living forms. When living forms appear, man appears also in the Pleistocene age. A reference to the table in which these changes are represented (p. 381) will at once show that it is hopeless to look for Eocene or Miocene man, and that his existence in the Pliocene is most improbable. The relation of the groups to one another proves further that each phase of the Tertiary is intimately connected with that which went before and that which followed after, and that the Tertiary period embraces all the events which happened from the close of the Secondary to the present day.

Discussion.

The President spoke of the great difficulties in the way of classification in the Tertiaries, whatever group of Invertebrata was chosen.

Prof. Seeley said that he had not quite understood in what respect Prof. Dawkins's classification differed from those already existing as founded on Mollusca. Much of the evidence on which he had to work was, he thought, very fragmentary. This objection especially applied to the older divisions of the Tertiary. He was not convinced that the genera could be used for purposes of classification as Prof. Dawkins had used them. The definitions which he himself would use of genera or species would differ from those used by Prof. Dawkins; and so different results would follow. Another objection that he had was to the assumption that animals had become extinct from climatal causes; for, historically, we know that man has destroyed many forms of life in Europe, and thus the differences between the Historic and Prehistoric faunas might be explained.

Mr. Charlesworth said the author had given no new factors to aid in the classification of the Tertiaries; for he had used the names founded on the old molluscan classification. He thought there were more extinct genera in the Crag than the author seemed to admit. In the Crag the Polyzoa were more related to the Miocene, the Mollusca to the Pliocene.

Mr. Whitaker said that he did not see where Prof. Dawkins's classification differed from the present one; for the Lyellian terms abounded in his paper, which should rather have been called "the range and evolution of Mammalia in Tertiary times." For himself he doubted whether the Crayford brick-earths could be called Middle Pleistocene and not Upper. Prof. Prestwich had long ago found the Musk-sheep in the Thames valley, near Maidenhead, in beds of much the same age as those at Crayford. As a working Tertiary geologist, he did not see how to apply Prof. Dawkins's system; for though he often got plenty of shells, he had never found a single mammalian remain in beds below the Pliocene. So how could he classify by Mammalia? He thought the system proposed was unpractical. If "doctors differ" as to the genera and species of Mammalia, the classificatory value of the latter is doubtful.

Rev. J. F. Blake said no doubt rocks in the field must first be studied stratigraphically; but the larger groupings were dependent on the fauna contained. This, he thought, was the line Prof. Boyd Dawkins had adopted; but he had not shown where his classification differed from the received one. He thought, however, that the Mammalia had already been used for classification of the Tertiaries.

The President remarked that, to his mind, the chief feature in the paper was its history of the Miocene fauna, which was so little known in Britain. Whether this mode of classification was novel or not, the way in which the facts were clearly massed was most valuable. He would not himself reject either mode of classification;

to the majority of students, however, he thought the Invertebrata would always be the more valuable.

Prof. Boyd Dawkins said he had not asserted that the Invertebrata were of no use; but he would ask, Could the more modern Tertiaries be classed by their Invertebrata? In the older beds no doubt the Invertebrata were of use in classification. He had used the old terms because he did not see any reason for inventing new ones. He had never asserted that the mode of classification was new; but he would be glad to learn where the method which he had adopted in applying it was to be found. He believed that the system he had proposed would be found to be more than a "parochial" system, and to apply to America and Asia equally with Europe.

30. NOTE *on* PSEPHOPHORUS POLYGONUS, *v. Meyer*, *a* NEW TYPE *of* CHELONIAN REPTILE *allied to the* LEATHERY TURTLE. By Professor H. G. SEELEY, F.R.S., F.G.S., &c. (Read May 12, 1880.)

(PLATE XV.)

WHEN I was in Vienna in the spring of 1879, Franz Ritter von Hauer, the Director of the Imperial Geological Survey, requested me to examine and describe the remarkable organism on which Von Meyer had founded the genus *Psephophorus*, which, although noticed by himself, by Von Meyer, and, more recently, by Dr. Fuchs, has never been figured. Its nature was at first sight so problematical that opinion leaned to the conclusion that it was the dermal covering of an Edentate closely allied to the Armadilloes. The dorsal surface of the fossil was perhaps insufficient to settle this question without a good deal of comparative work; but Von Hauer courteously allowed me to partially develop some fragments of bones, which are imperfectly preserved on the underside of the intractable sandstone matrix of the slab; and these fragments of procœlous vertebræ proved to be altogether reptilian; and though differing from the vertebræ of known reptiles, yet, by the forward projection of the zygapophyses, they indicate the animal to be Chelonian, and therefore show the fossil to be more nearly allied to *Sphargis* than to any other type in the Chelonian order.

When Von Meyer first gave a name to this genus ('Jahrbuch,' 1846, p. 472), it was only known to him by isolated dermal plates; but subsequently a drawing was sent to him by Partsch, and on that he made a further note in the 'Jahrbuch' for 1847 (p. 579). This specimen, then in Pressburg, he describes as a fragment of a carapace, containing seventy bones touching each other, and showing the impressions of many others. Among these dermal bones rises a middle row, in which the plates are longer and more evenly pressed together in front and behind, while the other plates are placed together irregularly. He adds his conviction that it may be referred to the Dasypodia. It remained without further notice till 1868, when Von Hauer, in the 'Verhandlungen der k.-k. geologischen Reichsanstalt' (p. 387), mentioned briefly that the fossil had been acquired for the Museum of the Imperial Geological Survey in Vienna. He also, in 1870, in the same publication (p. 342), makes a note on *Psephophorus*, mentioning that the museum had acquired not only the original type specimen, but a second larger slab, fitting the first, and containing a larger portion of the same carapace; for while the first piece contained six median plates, characterized by a raised keel, extending in a straight line, and sixty-four smooth lateral plates in a connected position, on the second slab of sandstone are five more median plates and nearly a hundred more lateral plates. These form together an even arched shield, about thirteen Vienna inches long, and fifteen at its greatest breadth. Numerous bony plates are said to be scattered through the mass of the sandstone, besides other bone-fragments; and Von Hauer considers that there is a second shield, which lies parallel to the first, and under it, at an interval of scarcely half an inch. Von Meyer had made another short note on this fossil in the 'Berichte über die Mittheilungen von Freunden der Naturwissenschaften in Wien' for 1851 (p. 3), which Von Hauer well epitomizes by saying that although the animal had originally been regarded by Von Meyer as belonging to the Armadillo family, he subsequently showed the striking resemblance of the carapace from Neudörfl with one from the Zeuglodont Limestone of North America, which Müller had figured and compared with the dorsal shield of *Dermatochelys* in his work on *Zeuglodon*. But, beyond drawing attention to its resemblance to the *Psephoderma alpina* from the Upper Trias, and pointing out some resemblances which that genus presents to the crocodilian type of armour, Von Hauer expresses no opinion on the systematic position of the genus. Finally Dr. Th. Fuchs, in notes on his travels in Italy, printed in the 'Verhandlungen der k.-k. geologischen Reichsanstalt' for 1874 (p. 220), remarks that in the zoological department of the Museum at Florence he saw the remarkable shield of *Sphargis coriacea*; and adds, "the full resemblance to our *Psephophorus* is so evident that I cannot imagine that any one who had seen the two could remain a moment in doubt on this matter." Von Meyer appears to have inclined towards the Chelonian hypothesis, in consequence of Müller's account of the *Sphargis* in the Zoological Museum in Padua; and it only remained for Fuchs to confirm the accuracy of this interpretation.

The slab of hard sandstone in which the specimen is preserved is 46 centimetres long, and about 41 centimetres wide. It only shows a small portion of the shield, which originally covered the back of the animal, the principal part preserved being 33 centimetres long and 35 centimetres wide. It is divided into two portions by an elevated longitudinal median keel or crest. The lateral parts are inclined to each other at an angle of about 155 degrees. The keel does not appear to be quite straight; and it would be difficult to assert positively that it occupied a lateral position in the body, though this probably was the case. The keel is rounded, and formed by a single row of polygonal plates, portions of eleven of which are preserved; nine occupy a length of 28 centimetres. Nothing could be more remarkable than the extreme irregularity of size and form of the ossicles which make up the lateral portions of the carapace. Some small ossicles are nearly circular, others ovate, triangular, subquadrate, but mostly of irregular forms with five, six, or more sides, which are sometimes convex, sometimes concave, and often with sharp angles at the points where they join the neighbouring little plates. Occasionally a minute plate occurs which is hardly a centimetre in diameter; but most of the plates are from two centimetres and a quarter to two and a half centimetres in diameter. Their substance is very dense, almost like the palatal teeth of *Plethodus* or the armour of a ganoid fish. There is no trace of the plates having been ankylosed together; for although they for the most part still retain their natural positions, they have separated sufficiently to show that the original connexion was maintained by a fibrous or coriaceous investiture. On the dorsal surface the plates, except in the median keel, nearly all show a beautiful radiating sculptured ornament, which certainly recalls that seen in some of the larger Armadilloes, rather than the condition in any reptile. On the under surface the plates are perfectly smooth. As arranged, the transverse measurement of the plates appears to be greater than the longitudinal measurement, five plates occurring transversely in one place in a distance of twelve centimetres, and six or seven occupying the same distance longitudinally.

It is difficult to say which should be regarded as the anterior part of the fossil, as the remains are so fragmentary that they give no indication whatever of its complete form or size; but I incline to believe, from the analogy of the curved ridge in *Sphargis*, that it is an anterior fragment from the left side. The plates are remarkable for their thickness, which sometimes amounts to nearly a centimetre, though most of them are thinner. Towards one corner of the slab are a few plates, much thinner, partly covered with matrix, which look as though they might have belonged to an under or ventral armature; but having regard to the state of preservation of the fossil, it would be unsafe to overlook the probability that they may be a portion of the carapace displaced and inverted, or of its margin, which would naturally have an inverted position. But *Psephophorus*, unlike *Sphargis*, may have also possessed a ventral shield of thin plates. A question may arise as to whether the fragmentary bones on the other side of the slab, which is about six centimetres thick, are portions of the skeleton of the same animal; but all probabilities seem to me to lean in that direction; for this fossil was evidently stranded, much as porpoises and other animals are thrown up on sandy shores at the present day, and the skeleton, becoming knocked to pieces, has been scattered. The resemblance of the carapace to that of a mammal is certainly sufficiently close to have justified any one in so regarding it; and the large size of the armour-plates, as well as their sculptured surfaces, would support this resemblance; but the elevated rounded keel, increasing in height as it passes onwards, with the somewhat flattened sides of the shield, are more in harmony with *Sphargis*; and if skeletons of the covering of *Sphargis* had been prepared in our Museums, it is certain that the same kind of irregular arrangement of the plates would have been recorded. There is little, except the relatively large size of the plates in the fossil and their perfect ossification, to distinguish them from the comparatively small elements which make up the bony skeleton of the covering of the leathery turtle.

So far as I am aware, the dermal shield of *Sphargis*, though often figured, has never had its osteological characters described; for the thin epidermic covering conceals bones which constitute a shield which is only comparable to a tessellated pavement, corrugated by the seven longitudinal ridges which extend along it. The main median ridge is most elevated posteriorly; but the three lateral ridges on each side maintain about equal elevation throughout their respective lengths, and converge towards each other very slightly anteriorly, and more markedly towards the posterior end. A specimen in the British Museum has a length of a hundred and fifty centimetres; the greatest transverse width round the curve of the back is more than a hundred centimetres, though the width from side to side in a straight line in the same position is not much more than seventy centimetres. The bones which form the median ridges are often three centimetres long, and abut against each other by transverse sutures, much as in the fossil; but the ridges in the recent *Sphargis* are sharper and more broken by irregularities, owing to the fact that some plates have the ridge developed to a greater height than others. In the wide part of the carapace, the transverse width between two lateral ridges is about sixteen centimetres, and in this distance fourteen or fifteen polygonal bones may usually be counted. Anteriorly the plates become rather smaller, and seventeen or eighteen plates may be counted between two ridges; and it is also here observed that the transverse measurement of each plate is usually greater than its longitudinal measurement. The plates mostly vary from half a centimetre to over a centimetre in diameter. Some of the plates appear to give indications of a slight radiated surface-wrinkling, like that seen in some parts of the fossil; so that, as Müller first suggested and Von Meyer afterwards asserted, the resemblance of *Psephophorus* to *Sphargis* is close, and quite justified Fuchs in stating that it was only necessary to see the two types to admit their general identity. In fact, there is nothing but difference in the size of the plates to distinguish the two genera, as far as the shield is concerned. It is, of course, impossible to say how many longitudinal ridges may have extended along the carapace of *Psephophorus*. If there were many, the interspaces between the ridges certainly wanted the concave character visible in the recent genus; and this apparent flatness of the carapace leads me to suspect that in *Psephophorus* the ridges may have been fewer than in *Sphargis*. The slight longitudinal curvature visible in the median ridge in the fossil, together with the slight transverse elongation of the bony plates, would lead me to regard the specimen as being probably part of a lateral ridge from the anterior portion of the shield, and not far from its margin; for what has appeared to be the under shield formed of thin plates, imperfectly seen at its posterior end, where many plates of the skeleton have been broken away, would well correspond to that part of the carapace of *Sphargis* which is bent round inferiorly at the outer sides of the shield; so that when fossilized, these portions might then present the appearance of two shields superimposed on each other.

It will readily occur to any one familiar with the Chelonia that the type which is represented by *Sphargis* and *Psephophorus*, differs from all the other members of the order, not only in having the ribs entirely separate from the carapace, but also in the fundamental plan upon which the representative of the carapace itself is constructed; and I believe that we have here an indication of a primary division of the Chelonia to which palæontological discoveries may hereafter give more importance than can at present be claimed for it. From the point of view of evolution, it may fairly be anticipated that the pavement-shielded type of Chelonian preceded that in which the dorsal shield is formed of symmetrical bones. Perhaps the most remarkable character in the dermal skeleton of *Sphargis* is the fact that the bones of the plastron, although only forming an outer ring to the ventral surface, are already defined and homologous with those of the ordinary Chelonian, in which the carapace is specialized. And this leads me to draw attention to the fact that the dermal bones of *Sphargis*, which may be detected without difficulty on the dorsal surface of any ordinary shield, are altogether invisible on the interior side of the shield, which was in contact with the neural arches of the dorsal vertebræ and the slender flattened ribs; so that it is quite evident that the ordinary carapace of a Chelonian is in no way represented by the dermal skeleton of *Psephophorus* or *Sphargis*. Impressed by the fact that the dorsal ribs of Crocodiles bear upon their hinder margins plates of fibro-cartilage, which in the *Hatteria* also exist and are sometimes converted into bone, and believing that these plates are homologous with the epipleural elements or uncinate processes which become greatly developed and blended with the ribs of certain birds, I have been led to speculate on the probable occurrence of such cartilaginous elements upon the dorsal surfaces of ribs of Chelonians, and to believe that the development and ossification of such plates upon the Chelonian rib would lead to a transference of the osseous matter from the superficial portion of the skin to its deeper-seated layer, and hence to the growth of epipleural plates, which would become the costal plates of the carapace. The granulations on the shield of *Trionyx*, on such a view, indicate dermal bones like those of *Sphargis*—which were originally separate, but have become blended with the bony elements which were subsequently developed beneath them. The costal plates are said to be always distinct from the ribs in the young turtle when first hatched. They are certainly very small in the young of some of the Trionychidæ, in which, indeed, they remain throughout life but partly united with the endoskeleton. It is the impossibility of logically accounting for the development of the Chelonian carapace without the aid of this hypothesis that leads me to attach more than ordinary importance, in a classificational point of view, to the characters presented by *Psephophorus*, which are only otherwise paralleled by the small specimen which Müller figures from the Zeuglodont Limestone of North America, and by the living *Sphargis*.

The best-preserved vertebral fragment (Pl. XV. fig. 2), as already mentioned, is Chelonian in its characters. A few scattered plates occur intimately associated with the vertebræ. Altogether there are fragments of five vertebræ preserved. None shows the whole of either centrum or neural arch; nor do they collectively throw much light upon each other. It is difficult to affirm with certainty the region of the vertebral column to which they belong, though I am disposed to believe that they chiefly pertain to the later cervical or dorsal series, and there is a fragment which appears to be a portion of a rib. The best-preserved specimen rests on its side, partly imbedded, and fractured through its length. The centrum is about five and a half centimetres long, or but little longer than the later cervical vertebræ of *Sphargis*. It shows cancellous tissue along its fractured length; but in the processes this is covered by a dense outer layer. The base is concave in length, the constriction being greatest towards the anterior end. The anterior end is cupped concavely, is about two and a half centimetres deep, and has the articular cup vertical. The posterior articular end was a well-rounded ball, and considerably deeper than the anterior cup. The neural arch is, unfortunately, much less perfect than the centrum. Projecting anteriorly just above the neural canal is a small process; and above this is the right side of the neural arch, which reaches forward and upward in a wedge-shape, having a total length, from its posterior termination near the middle of the centrum, of about five centimetres, and gives no indication of facets of the zygapophyses, which could not have looked inward. Its total height from the base of the centrum, as preserved, is about six centimetres; the distance for which it extends anterior to the articular face is about two and a quarter centimetres. From the middle of the right side of the centrum, at about its junction with the neural arch, is given off a transverse process, which has a strong expanded base, is somewhat compressed, and directed outward and, possibly, upward. It is imperfectly preserved at the end. Imperfect as these indications are, they amply show that we have here to do with an animal which differs not only generically from Chelonians, but in characters in which all other genera agree.

Two other centrums are exposed so as to show their length. Both appear to be moderately concave at the expanded anterior end, and slightly convex at the narrower posterior end. These vertebræ are about five and a half centimetres long. One shows the hinder part of the centrum to be rounded from side to side (it probably had a descending process in front); the other shows a strong flattened transverse process, which is directed slightly forward, and expands a little anteriorly towards its free end. The fourth fragment indicates a smaller vertebra, apparently caudal, which has the prezygapophyses strong and short, and curved apparently forward and upward, with the facets looking inward. The points in which these vertebræ differ from those of all Chelonian reptiles are, the apparently massive character and great development and height of the neural arch, and the extraordinary transverse processes, which are both ankylosed to the centrum.

In Chelonians such processes are limited to the caudal region; but in no respect have we here the characteristics of caudal vertebræ, except in the small and imperfect specimen, in which the end of the centrum appears to be flattened. And I believe the evidence rather points to the vertebræ belonging to the later cervical or dorsal region.

It would appear that the absence of transverse processes in the Chelonian, while so characteristic of the crocodile in the dorsal region, may have come to be correlated with the mode of development of the carapace, and the consequent way in which muscular tension on the bones was changed ; but when the carapace is free from the ribs, the condition of the dermal skeleton is not very different, as regards its position and relation to the endoskeleton, from what obtains among the Crocodilia; and although *Sphargis* does not develop transverse processes for the attachment of the ribs, it must be remembered that *Sphargis* is the only member known of a great division of the Chelonia which must have included many types of organization, and is probably as important morphologically as all the other Chelonia put together.

The anterior position, however, of the transverse process in one vertebra, just behind the anterior articulation, is altogether in harmony with the Chelonian plan. There is no indication that the ribs were attached by a double articulation to the transverse processes, as among Crocodiles; but then it may be remembered that this character is only found in the first six or seven dorsal vertebræ of the crocodilian skeleton ; so that I am led to believe that the many points in common, both in soft and hard structures, which the Chelonian and Crocodilian orders possess, lead us here to look for a group which may have more nearly connected them than any form previously known. In the characters which can be compared, *Psephophorus* seems to me to differ more from existing Chelonians than they differ among themselves ; and hence I believe it will prove to be the type of a new subordinal division, which, however, it is impossible at present to fully define in the absence of the more important osteological characters. The following classification gives in a condensed form the results to which this study of *Psephophorus* has led up.

The characters of the carapace indicate three primary divisions of the Chelonian order:—First, the

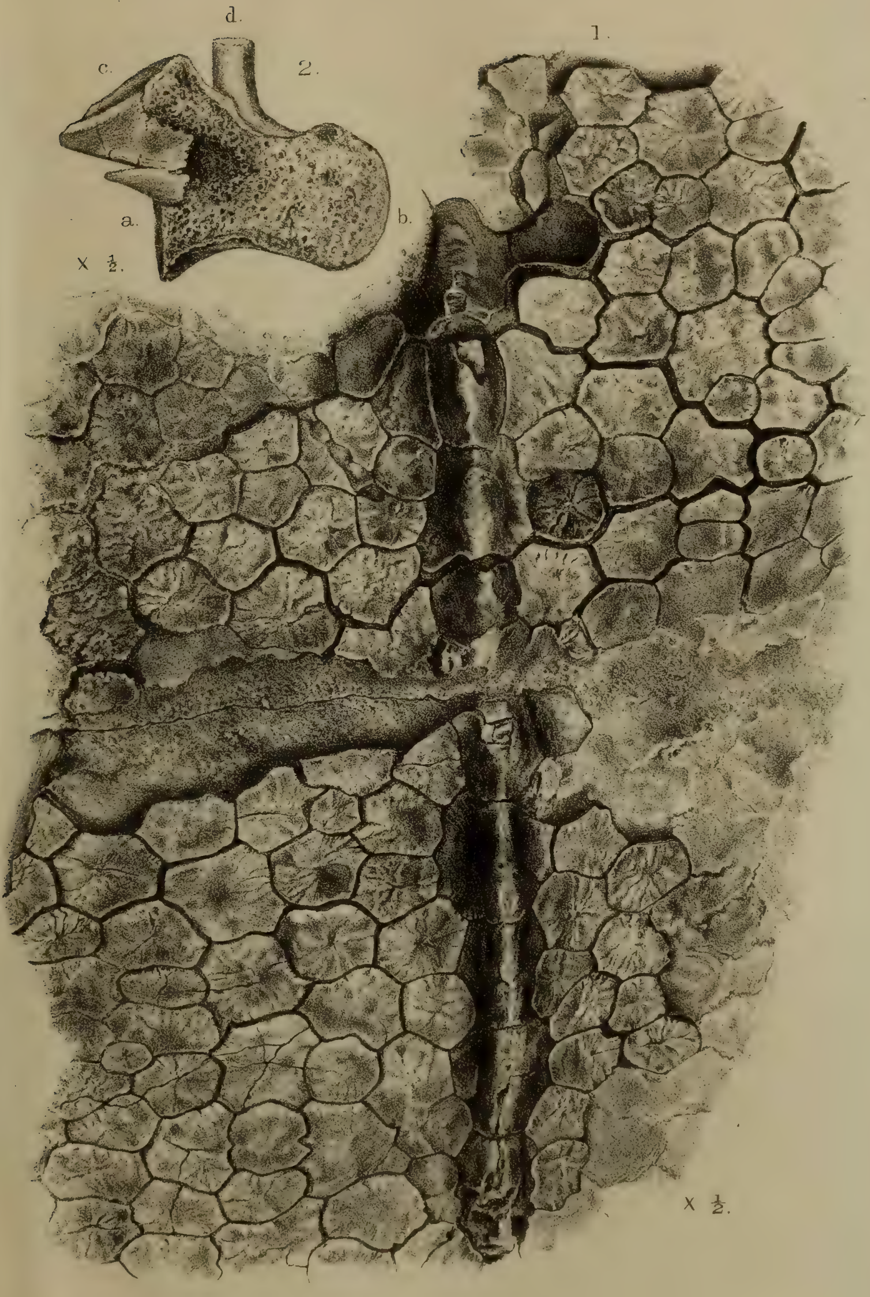
ASPIDOCHELYIDÆ, comprising Turtles, Emydians, and Tortoises, in which the symmetrical bony carapace is covered with symmetrical horny scutes ; secondly, the

PELTOCHELYIDÆ, including the Trionychidæ, in which the symmetrical bony carapace has a granular surface-structure, and is covered by an undivided dermic substance without scutes ; and, thirdly, the

DERMATOCHELYIDÆ, represented by the Sphargidæ, in which the carapace is not developed, but is represented by a bony skeleton within the skin, resembling a tessellated pavement.

The remains are from Neudörfl, near the river March, which forms the boundary between Austria and Hungary. Von Hauer refers the sandstone there to the second or upper Mediterranean series of the Austrian Neogene. Fish-remains from this formation have been described by Count Münster in his 'Beiträge zur Petrefactenkunde;' and the deposit also yields Gasteropods, Bivalves, and Echini.

I would express my grateful thanks to Professor Suess for direct-



A.S. Foord lith

Mintern Bros. imp.

PSEPHOPHORUS.

ing my attention to this remarkable specimen; to Director von Hauer, not only for facilities afforded me in studying the specimen, but for the beautiful photographs which accompany my paper; to Dr. Günther, of the British Museum, for the opportunity of demonstrating its affinities with *Sphargis* by studying the skeleton of that type; and to the Council of the Royal Society for assistance in investigating this type in a distant locality.

EXPLANATION OF PLATE XV.

(Figures half the natural size.)

Fig. 1. Portion of dermal shield of *Psephophorus polygonus*, Von Meyer, showing part of an elevated longitudinal keel with polygonal plates on each side of it, which differ in form and size and mostly show a superficial radiated ornament. Beyond the point where the figure 1 is placed, the slab shows thin plates with a smooth surface, which may be marginal.

2. Vertebra from the under side of the slab, probably cervical, fractured longitudinally and imbedded in the matrix. *a*. The anterior cup. *b*. The posterior ball. *c*. A fragment of the neural arch blended with the centrum. *d*. Transverse process of the right side, imperfect, but directed outward and upward.

Discussion.

Mr. Hulke agreed with the view taken by Prof. Seeley of the specimen. As to the classification proposed, it would require careful consideration.

Prof. Duncan said the possible existence of something like ribs in the cervical region was interesting. The position of the shoulder-girdle in the Chelonians was always a difficulty. This, however, might have been gradually assumed during the early stages of life; but the presence of cervical ribs rendered the former existence of the scapula outside the dorsal ribs and in front very difficult of comprehension. The classification of the Chelonians was at present in great confusion. He thought there was much to be said for the simplicity of Prof. Seeley's classification.

The President asked whether these dorsal-shielded forms preceded the others in time or not.

Prof. Seeley said the specimen was Pliocene, *i. e.* the newer division of the Tertiary. It comes from Neudörfl, near the borders of Hungary and Austria, and is associated with Manatees and Chelonians of ordinary type. It has been compared by von Hauer with *Psephoderma alpina* from the Trias in the Munich Museum. This specimen he had seen, which he thought was not a Chelonian, though it might be an antecedent form or even a fish, like *Ostracion*. It was curious that the Mesozoic Chelonia belong, so far as known, to those with well-developed carapaces; but he thought that *Sphargis* was nevertheless the more primitive type.

31. Description *of* Parts *of the* Skeleton *of an* Anomodont Reptile (Platypodosaurus* robustus, Ow.) *from the* Trias *of* Graaff Reinet, S. Africa. By Prof. Owen, C.B., F.G.S., &c. (Read April 28, 1880.)

[Plates XVI. & XVII.]

In a former paper † a dental character in a Triassic reptile was indicated which is repeated in some implacental members of the Mammalian class. I have also noticed a like correspondence in the skeleton of another reptile from the same formation in South Africa ‡.

Pursuing the work of extricating from the matrix the Triassic fossils since received from that continent, indications still more interesting of such relationship have come to light, which I now proceed to submit to the Geological Society.

The evidence of the genus and species of extinct reptile above named, forming the subject of the present paper, consists of a series of seven thoracic vertebræ, with portions of ribs, a sternal bone, scapula, and a right humerus, all cemented to a mass of dark quartzose rock. A smaller mass included a femur with the pelvis; but the latter is still under the chisel. The parts exposed in the first block are the left side of the vertebræ, the scapula, and the whole of the anterior surface of the humerus, which bone remains attached, somewhat behind its natural position, to the right side of the present portion of thorax.

Vertebræ.—Of each vertebra the centrum is subcompressed; the sides are slightly concave lengthwise between the thick convex borders of their mutually articulating terminal surfaces; these are concave (Pl. XVI. fig. 1, *a*, *b*), the hinder one (*b*) is the deeper; the extent of intervening part of centrum (*c*) is 5 lines. The external smooth lateral surfaces slightly converge towards the narrow inferior one (ib. fig. 2). The neurapophysial suture (ib. fig. 1, *n′ n′*) is unobliterated.

The neurapophysis (ib. fig. 3, *n*) ascends, slightly contracting antero-posteriorly and inclining outwards to form a neural platform, from the sides of which the usual di- and zygapophyses are developed; from the summit of the arch rises a neural spine, *n s*. To the diapophyses of two of these vertebræ the proximal portions of the ribs (ib. fig. 3, *pl*) are attached; these are subcompressed and feebly channelled along the side exposed.

The following are dimensions of the above parts of the thorax:—

* πλατὺς, broad; ποὺς, foot; σαῦρος, lizard.

† "On *Cynodraco major*," Quart. Journ. Geol. Soc. vol. xxxii. 1876, p. 960; 'Descript. and Illustr. Catalogue of the Fossil Reptilia of S. Africa,' 4to, 1876, p. 70.

‡ 'Descriptive and Illustrated Catalogue,' p. 48.

	in.	lin.
Length of centrum	1	6
Height of centrum	1	9
Depth of articular terminal concavity (hinder)	0	9
Height of neurapophysis including postzygapophysis	1	6
Height of neural spine	2	0
Length of base of spine	0	9
Length of summit of spine	1	0
Thickness of summit of spine	0	4
Breadth of rib	0	6
Thickness of rib	0	4 to 3
Length of best-preserved rib	7	0

Of the genera of S.-African Triassic Reptilia hitherto indicated by vertebræ (not differentiated like those of the "tretospondylian" group), the following differences are shown in comparison with the present genus.

The dorsal vertebræ of *Platypodosaurus* are smaller than the caudal ones of *Massospondylus** the centrum of which is 4 inches 3 lines in length. Of *Pachyspondylus** the caudal centrum is 2 inches 6 lines in length; that of *Leptospondylus** is 2 inches 2 lines in length. The formal differences of these caudals suggest more marked ones in the thoracic vertebræ of the same genera; but none have as yet been received.

The vertebræ of *Platypodosaurus* agree more closely with those of the Anomodont Reptilia (*Dicynodon* and *Oudenodon*) †; they differ in the minor depth of the terminal concavities from the vertebræ of *Kisticephalus* ‡ and *Anthodon*§.

The nearest approach to the biconcave structure of vertebræ in existing Mammals is shown in a Monotreme (*Echidna*) in which the unossified part of the ends of the centrum is dense at its periphery, and presents a definite cavity (*a*) filled with fluid || (Pl. XVI. fig. 4).

Sternum.—Save in the instance of *Kisticephalus microrhinus* and *Saurosternon Bainii,* I have sought in vain for evidences of sternal structure in the S.-African reptiles until the exposition of the fossils here described.

The flat symmetrical bone (Pl. XVI. fig. 5), hexagonal, but with the angles so rounded off as to approach a circular form, I regard as the anterior one of the sternum proper, repeating in its large relative size that which is usually unossified in modern Lizards, but which is well ossified in *Ornithorhynchus* (ib. fig. 6, *a–c*).

* The vertebræ referred to the above genera are described in my 'Catalogue of the Fossil Reptilia and Pisces in the Museum of the Royal College of Surgeons of England,' 4to, 1854, pp. 97–100. They were transmitted by Ch. E. H. Orpen, Esq., M.D., from the Drakensberg range of mountains, near Harrismith, Cape of Good Hope, and from a formation which, by indications afforded by the donor's letter, I stated to be "probably of the age of the New Red Sandstone in Europe."

† Cat. S. Afr. Reptilia, 4to, 1876, pp. 40, 43, pls. xxxv., lii., liii.

‡ *Op. cit.* p. 63, pl. lxix.

§ *Ib.* p. 88, pl. lxx. fig. 2.

|| Art. *Monotremata,* Cyclop. of Anat. vol. iii. 1841.

As in this Monotreme, the fossil shows an anterior articular surface (*a*, *a*′) indicative of a more advanced "episternal" element. The present anterior "sterneber" is 6 inches in length and the same in breadth; the average thickness may be put at ½ an inch, increasing at the articular parts of the margin, of which there are four, the lateral ones (*b*, *b*′) being the broadest, swelling anteriorly to a thickness of 1¼ inch. The swelling in the lateral (*b*, *b*′) and posterior (*c*, *c*′) joints is towards the outer surface of the bone; that of the anterior joint (*a* *a*′) turns towards the inner one.

The outer surface is feebly concave between the lateral joints, and also between each of these and the hinder joint; transversely, below the lateral joints, it is as feebly convex; the surface is smooth, with faint lines radiating towards the periphery.

The inner surface is feebly concave both lengthwise and across; it is traversed by a low median narrow rising, hardly to be called a ridge, which is thickest and most prominent at the anterior joint (*a*′) and subsides before reaching the posterior one. This latter surface indicates the abrupt diminution of size, especially breadth, of the second sternal bone which had been articulated therewith.

I conclude from the character of that surface that such continuation of a sternal series was present, as in the Chamæleons and Scincs, and that the hinder surface (*c*, *c*′, fig. 5) gave partial attachment to a pair of sternal ribs, not total as in *Varanus* and *Iguana*. The lateral articulation (*b*, *b*′) shows two convex surfaces divided by an oblique groove; the lower and larger surface probably gave attachment to a sternal rib, as in *Ornithorhynchus* (fig. 6); the upper, narrower and longer one may have joined the coracoid, as in Monotremes. The relative size of the foremost sternal bone, if followed by a second of the size indicated by the joint-surface with the first, would offer a Monotrematous character, but one of an importance secondary to that which would be afforded if the anterior articular surface of the large sternal bone supported an episternal element of the **T**-shaped character shown in both *Ornithorhynchus* and *Echidna*, as well as in *Ichthyosaurus* and most modern Lacertians.

Such is the character of that bone in the labyrinthodont fossil transmitted, under the name *Batrachosaurus*, by Mr. A. G. Bain to the British Museum, and subsequently called *Saurosternon* by Prof. Huxley *; also in the specimen described and figured by me in the 'Catalogue' of Mr. Bain's fossils, on which I was at that time engaged †, and in which it is noted that "the episternum shows the clavicular groove on each transverse branch, as in that of *Labyrinthodon leptognathus*" ‡. This groove for the reception of the clavicles is more feebly marked in *Ornithorhynchus*, and is obliterated by confluence of the clavicles therewith in old animals, as in the specimen figured by Clift to show the resemblance of the scapular arch in that mammal to the same part of the skeleton in *Ichthyosaurus* §.

* Geological Magazine, vol. v. 1868, p. 201, pl. xi. fig. 1, *c*.

† 'Catalogue' &c., 4to, 1876, pl. lxx. fig. 3. ‡ *Op. cit.* p. 69.

§ "As this form of the sternum (in *Ichthyosaurus*) appeared at the same time quite new, I was very anxious not to fall into an error, and was reexamin-

The correspondence between the aquatic reptile and mammal is not carried out in other parts of the skeleton of the Oolitic Ichthyosaur; but in the older form under description I proceed to show such in the scapula, in the chief bone of the limb articulated to the complex scapular arch, and in the femur.

Scapula.—In the 'Catalogue of South-African Fossil Reptilia' two types of scapula are described and figured—one in a species of *Dicynodon* *, the other in a species of *Kisticephalus*†. In the former the marginal acromion shows an articular surface for junction with an epicoracoid; in the other the acromion is a thinner plate and does not show such distinct articular surface. The resemblance in these reptilian scapulæ to that bone in the Monotremes is noted ‡ in the 'Catalogue.'

The right scapula of *Platypodosaurus* (Pl. XVII. figs. 1 & 2) was transmitted in a separate block of matrix, which had been detached from that enclosing the portion of the thorax with the right humerus; it was part of the same skeleton. In clearing away the matrix from such detached scapula the terminal phalanges of four digits of, most probably, the fore paw of the same reptile were exposed, adhering by a moderate thickness of matrix to the inner or concave surface of the scapula (ib. fig. 2). This bone, as in most Reptilia, and as in the *Ornithorhynchus*, is narrow in proportion to its length; a portion only of the glenoid surface for the humerus is preserved at the distal end. The length, following the slight bend or curve of the bone, is 10 inches; the basal breadth is $4\frac{1}{2}$ inches; but some portion is here wanting from the anterior border.

The entire bone might have shown a breadth like that of *Kisticephalus*, but more restricted towards the proximal end (a, b) as in *Dicynodon* §. Sufficient of the fore margin is preserved to show that it describes, as in *Dicynodon*, a sigmoid curve convex along the proximal half (a to b); then, as the bone loses breadth, it becomes concave, this curve being deepened by the production of the spine or acromion, e, which terminates the fore border $2\frac{1}{2}$ inches above the distal articular surface. But the fore border is as it were resumed near the inner side of the acromion, completing the concave curve of that border of the scapula, e', as it advances to the coracoid articular surface, f, here broken away. Hence the spine or acromion, e, may be said to rise from part of the anterior border, or costa, and also from the

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ing, with Mr. Clift, the different specimens, when it struck him that there was something similar to this mechanism in the sternum of the *Ornithorhynchus paradoxus*" (Home, Sir Everard, in 'Phil. Trans.' 1818, p. 32, plate ii.). The chief value of the papers on the "Fossil Remains of an Animal more nearly allied to Fishes than any of the other classes of animals" (Phil. Trans. 1814, p. 576; 1816, p. 320; 1818, p. 32; and 1819, p. 216, *Proteosaurus*) is yielded by the accurate and beautiful figures of the first discovered parts of *Ichthyosauri* contributed by William Clift, F.R.S. Cuvier subsequently pointed out the correspondence of the lacertian sternal apparatus with that of Monotremes, in the concluding volume (v.) of his 'Ossemens Fossiles' (4to, 1824), p. 290.

* *Op. cit.* pp. 47, 57, pls. lxix. & lxx.

† *Ib.* p. 53, pl. lxix. figs. 8, 9.

‡ *Ib.* p. 48.

§ *Op. cit.* pl. lxx. fig. 1.

outer surface or dorsum near the anterior costa. The resemblance of the scapula of the *Platypus* to that of *Platypodosaurus*, in general form, is "increased by the origin of the spine close to the anterior costa, and by the spine being bent forwards so as to seem to form a continuation of the external surface of the scapula" *.

The external surface of the scapula of *Platypodosaurus* (Pl. XVII. fig. 1) is flat in the proximal or basal half (*a* to *b*), and is here marked by longitudinal striæ; it becomes convex, both lengthwise and across, at the distal or humeral half (*b* to *e'*), save where this expands beyond the acromion to form the coracoid articular surface, *f*, when it becomes concave both transversely and longitudinally. The hind border of the scapula, *c*, describes a concavity along its distal two thirds, its proximal third being straight, as in *Dicynodon leoniceps* †.

The inner surface (ib. fig. 2) is longitudinally concave, flattened at the proximal expansion; at the distal one it is transversely convex, swelling out to contribute to the humeral articular surface (ib. *d*), concave where it extends upon the beginning of the expansion for the coracoid joint. The acromion curves towards this aspect, and terminates in a thin border (ib. *e'*), showing no sign of an articular surface for an epicoracoid or clavicle, such as exists in *Dicynodon* ‡; in this respect the process resembles rather the acromion in *Kisticephalus* §. A clavicle or episternal may have been attached by ligament to the free margin of the acromion in *Platypodosaurus*.

The striated superficial markings on this and other bones of *Platypodosaurus* recall the character of those in some Labyrinthodonts. Fractures of the dorsum scapulæ, or convex outer surface, expose a lamellar or stratified texture of the bone; the surface of such lamellæ, exposed beneath a superficial compact layer a line in thickness, also shows, but more faintly, longitudinal striæ.

In *Echidna* (Pl. XVII. fig. 4) a ridge (*g*) is developed which represents the "scapular spine" of higher mammals, the second ridge and process (*e*) answering to the second "spine" in *Megatherium*; the latter alone is present in *Ornithorhynchus* as in *Platypodosaurus*; but the process (*e*) is common to both monotremes as to the Triassic reptile; and the term "acromion" is here applied to it, as by Meckel ‖ in his Monotreme.

Humerus.—The humerus (Pl. XVI. fig. 7) repeats the general proportions of that of *Pareiasaurus* ¶, with characters shown in the same bone of *Cynodraco* ** and *Dicynodon* ††; but its breadth in proportion to the length is exaggerated by a special production of a tricipital process (Pl. XVI. fig. 7, *d*) near the subsidence of the teretial ridge (*c'*). This additional characteristic is not developed in the Cape reptilian humeri above cited; but it is present in that bone of the

* Art. *Monotremata*, 'Cycl. of Anat.' vol. iii. (1847), p. 376, fig. 173, *g*.
† *Op. cit.* pl. lxx. fig. 1. ‡ *Ib. ib. e.*
§ *Ib.* pl. lxix. figs. 8 & 9, *e*.
‖ *Ornithorhynchi paradoxi* Descriptio Anatomica, fol. 1826.
¶ Catalogue, *ut suprà* (4to, 1876), p. 11, pl. xix.
** *Ib.* p. 19, pl. xxvii. †† *Ib.* p. 43, pls. xli. & xlii.

Ornithorhynchus (Pl. XVI. fig. 8) and *Echidna* (fig. 9), and also, though less marked, in certain Marsupials (*Phascolomys* * and *Nototherium* †).

The length of the bone here described is $10\frac{1}{2}$ inches; the breadth of the proximal end is $5\frac{1}{4}$ inches; that of the distal end is $5\frac{7}{8}$ inches; that of the shaft across the deltoid (*f*, *f*′) and tricipital (*d*) crests is $5\frac{3}{4}$ inches; below these crests the breadth suddenly decreases to $2\frac{1}{4}$ inches; and the thickness (ancono-thenal diameter) of the shaft here, including the bridge (*k*), is $2\frac{1}{2}$ inches.

The head or proximal articulation (*a*) is indicated by the greater breadth of the convexity of that end of the bone towards the entotuberosity (*c*), where it is $1\frac{1}{2}$ inch ancono-thenally; it is continued of similar character, rough as for syndesmosal articulation, but losing breadth, to the upper border of the ectotuberosity (*b*). The deltoid crest (*f*), continued distad and ulnad from this tuberosity for an extent of $6\frac{3}{4}$ inches, swells out into a rough surface at its end (*f*″), the narrower distal border of which extends radiad at right angles to the axis of the shaft and is continued into the bridge of bone (*k*) which crosses and completes the entepicondylar canal (*o*, *o*).

About halfway down the deltoid ridge a second lower one is continued from its thenal margin upon the thenal surface of the shaft (at *e*, *e*′), and represents the pectoral ridge.

The border of the humerus, continued from the entotuberosity (*c*), extends obliquely thenad, distad, and ulnad, subsiding upon the thenal surface of the bone (*c*′), and, with a similar thenal inclination of the deltoid ridge (*b*, *f*), renders the proximal third of the intervening thenal surface of the shaft (*g*) slightly concave transversely. This surface, regaining its level, continues distad uninterruptedly to the bridge (*k*). The thickened border or production of the humerus from the entotuberosity (*c*) may be regarded as the teretial ridge. A distinct process (*d*), to which the term "tricipital" seems applicable‡, extends, independently, from the radial border of the shaft midway between the angle of the entotuberosity and that of the entepicondyle (*i*). The extent of the base of this tricipital ridge or process is $2\frac{1}{4}$ inches; it projects $\frac{3}{4}$ of an inch from the line or contour of the radial border of the humeral shaft.

From the least radio-ulnar diameter of the shaft below the deltoid and tricipital crests, the bone rapidly expands to the breadth above noted, which includes the ent- (*i*) and ect- (*h*) epicondylar productions. The short narrower part of the humeral shaft is crossed obliquely by the "bridge" (*k*), the length of which may be put at 2 inches, its breadth at 8 lines. The length of the outlet (*o*′) of the entepicondylar canal is 1 inch 3 lines; its breadth is 5 lines. The distal joint-surface (*l*) for the antibrachium is developed from the ulnar half of the expanded distal end of the bone; it is simply convex, and projects mainly from the thenal surface of that end. The ectepicondyle (*h*) is continued proximad as a thick supinator

* Researches on the Fossil Remains of the Extinct Mammals of Australia (4to, 1877), p. 361, pl. ci. † *Ib.* p. 517, pl. cxxvii.

‡ As affording origin to part of the triceps muscle in Monotremes.

ridge (h') anconad of the ulnar border of the narrow part of the humeral shaft. The entepicondyle (i) forms an angular prominence terminating below the radial border of the shaft.

The above characters of the humerus of the *Platypodosaurus* have been deemed worthy of detailing by reason of the Monotremes presenting the nearest resemblance to such bone in the vertebrate series.

In these alone (*Ornithorhynchus*, Pl. XVI. fig. 8, and *Echidna*, ib. fig. 9) have I found such characters repeated, but even with some exaggeration of the proportions of breadth to length. The crests (f, c',), continued distad and palmad from the ento- (c) and ecto- (b) tuberosities, leave a deeper intervening concavity at the proximal part of the palmar surface of the shaft, almost defining, as by a low curved ridge-like border, such concavity in the *Echidna* (fig. 9, g). In both genera, also, besides the ridge extending distad from the entotuberosity, c, there is a distinct angular tricipital ridge or process (d) as in *Platypodosaurus*; and this is most developed in *Echidna*, though with a minor relative extent of the base.

The bridge (k)* is broader relatively than in *Platypodosaurus*; so much so in *Platypus* as to carry the entry of the entepicondylar canal to the radial margin of that expansion of the distal end of the humerus (fig. 8, o). The transverse development of the bridge is so much greater in *Echidna* (fig. 9, k) that it assumes the character of the palmar surface of the distal expansion of the shaft, and the entry of the canal is pushed, as it were, quite to the anconal surface, and the shaft thus seems to be perforated antero-posteriorly, but with the normal obliquity (ib. o').

Cuvier notes the transference of the articulation (l) for the antibrachium to the ulnar portion of the distal expanded end of the humerus in *Ornithorhynchus* †, and also the proportion of the distal breadth to the length of the humerus in that low *quasi*-reptilian type of mammal: both characters are exaggerated in *Echidna* (fig. 9).

The attachment of the large "teres major" to the ridge c', and the origin of a considerable part of the "triceps extensor cubiti" from the process d, in the Monotremes ‡, have suggested the terms applied to these ridges in the humerus of *Platypodosaurus*.

Manus.—Of the digits cemented to the concave surface of the scapula (Pl. XVII. fig. 2), that next the humeral end (v) shows the ungual, 3, and middle, 2, phalanges, with part of the proximal phalanx, on the hypothesis of the phalangial formula being the same as in fig. 5, copied from the subject of plate lii. figs. 2 and 3 of my 'Catalogue'§.

* In a humerus of a large *Dicynodon* recently transmitted by Mr. Thos. Bain, the ossification of the "bridge," which seems to have extended distad from the fore part of the shaft along the primitive ligament, has not completed the confluence with that part at the distal end of the bridge.

† "La poulie articulaire qui est ici tout-à-fait globuleuse, se trouve loin d'être placée au milieu de l'os; elle est au tiers externe." (Leçons d'Anatomie Comparée, ed. 1835, tom. i. p. 386.)

‡ Meckel, '*Ornithorhynchi paradoxi* Descriptio Anatomica,' fol. 1826; Owen, Art. *Monotremata*, Cyclopædia of Anatomy, vol. iii. 1841, p. 377, fig. 180.

§ *Op. cit.* p. 54, pl. lii.

The ungual phalanx is broad, subobtuse; in length 1½ inch, in breadth 1 inch 2 lines, that of the articular surface being 11 lines. The phalanx supporting the ungual one is 9 lines in length and 1 inch 3 lines in greatest breadth, its proportions being nearly those of the second phalanx of the fifth digit in the *Dicynodon* (?) above cited. The pair of convexities near the distal end of this phalanx indicate the bicondylar trochlea. The outer surface is abraded from the preserved distal end of the first or proximal phalanx. This digit, which I take to be the fifth or ulnar one of *Platypodosaurus*, is relatively shorter and thicker than in the *Dicynodon* (?) cited.

Of the next (fourth) digit (IV) a smaller fragment of the proximal phalanx is preserved. The second phalanx, 2, seems to have been one inch in length and the same in breadth. The ungual phalanx, 3, is 1 inch 7 lines in length, 1 inch 1 line in breadth; but all these phalanges have suffered abrasion of the exposed (dorsal or anconal) surface. The third digit (III) is represented by the ungual, 3, and a small part of the second phalanx; the former is 1 inch 9 lines in length and 1 inch 5 lines in breadth. The second digit (II) loses size; its ungual phalanx, 3, is 1 inch 4 lines long, 1 inch 1 line broad. Of the first or radial digit there is no trace; nor would the portion of matrix supporting the above-described bone be big enough to have preserved any trace of it had it existed.

Each of the ungual phalanges are slightly deflected. The digits have formed part of the left fore foot. The breadth of this paw, if, as is most probable, it was pentadactyle (as in the subject of pl. lii. fig. 2, *op. cit.**), may have been 8 inches. From the relative length of the second phalanges of the fourth and fifth digits compared with those of the above subject, the paw of *Platypodosaurus* seems to have been somewhat shorter in proportion to the breadth. The ungual phalanges are more obtuse; the terminal angle is less produced. The claws they supported appear to have been adapted rather for fossorial work than for prehension or laceration of a struggling prey.

Though relatively shorter, the ungual phalanges have more the proportions of those of *Echidna* than of *Ornithorhynchus*; they differ still more from the homologous phalanges in the smaller Cape reptile (fig. 5).

Femur.—At the time (1876) of the publication of the Catalogue of South-African Fossil Reptilia I had but insufficient data for a description of the femur in any species. A proximal portion of that bone in *Pareiasaurus*† (Pl. XVII. fig. 8) affords, however, a few characters for comparison with the femur of *Platypodosaurus*. The trace or impression of the hind limb in *Saurosternon* indicates the femur to be somewhat slender and a little longer than the humerus. In *Saurosternon Griesbachii*‡ it is one third longer and there is a trace of a "third trochanter" projecting slightly from the inner surface of the shaft; but no such trace is shown in the specimen of *S. Bainii*.

* On this hypothesis the ungual phalanx of the innermost or first digit, I, is added in outline to those in fig. 4.

† *Op. cit.* p. 13.

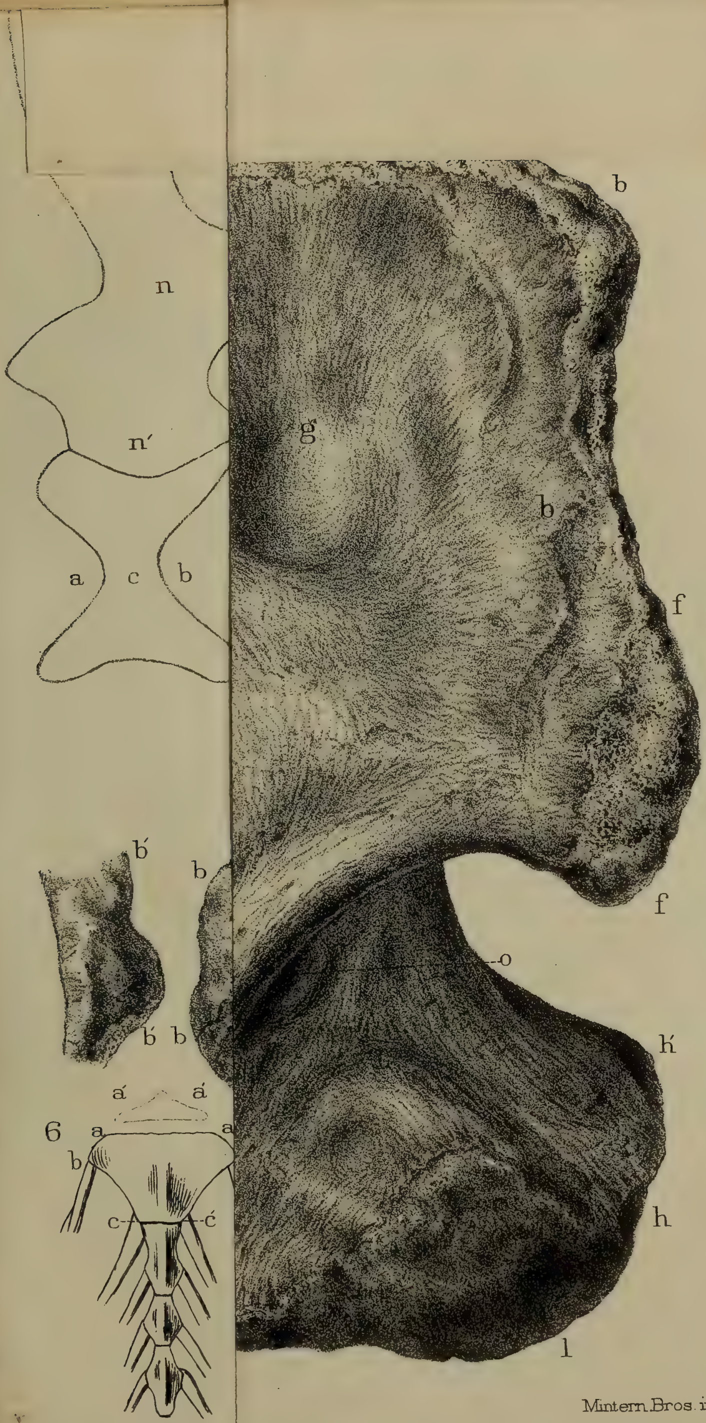
‡ *Ib.* p. 88, pl. lxx. fig. 4.

Of *Platypodosaurus* the proximal portion of the right femur (Pl. XVII. figs. 6 & 7) was successfully extricated from the matrix; it is 7 inches in length, 2 inches across the longer diameter of the shaft at the fractured end. But what proportion of the length of the bone is preserved cannot be determined from the specimen; it seems to include at least one half of the femur. So far as the shaft is preserved, there is a feeble trace of a small or third trochanter close to the inner border. The outer or great trochanter (ib. *b*, *b′*) is remarkable for its extent longitudinally, which measures 5 inches and terminates abruptly at almost a right angle with the shaft. The great trochanter is relatively shorter, and more gradually subsides upon the shaft, in *Pareiasaurus* (ib. fig. 8, *b*, *b′*). From the upper part of the head of the femur (*a*) what answers in *Platypodosaurus* to the neck (fig. 6, *c*) extends outward more horizontally than in *Pareiasaurus* (fig. 8, *c*), but equally without any concavity or depression, and gradually thickens from 9 lines across near the head to 1 inch at the proximal end of the great trochanter. The anterior surface between the head and great trochanter is slightly concave through the prominence of these parts; and there is no eminence dividing that part of the anterior surface of the femur "into two facets," as in *Pareiasaurus**. The posterior surface of the proximal portion of the femur of *Platypodosaurus* shows a pair of low broad ridges dividing such surface into three subequal longitudinal tracts, the two outer ones of which are slightly concave across. There is a submarginal trace of a "small trochanter;" but such process, in the femur of *Pareiasaurus* (ib. fig. 8, *f*), projects like a tuberosity from the middle of that surface. A transverse polished section of the fractured end of the femoral shaft of *Platypodosaurus* (ib. fig. 6 *a*) exhibits a well-defined medullary cavity of corresponding elliptical form; but it is not more than 8 millims. in long diameter, that of the section exceeding 2 inches. In *Pareiasaurus* the peripheral portion of the femoral wall, for an extent of about one seventh of the long diameter of the section of the shaft (ib. fig. 8 *a*), presents a compact structure; but this somewhat suddenly degenerates into a looser spongy texture, the large cells or interspaces of which are occupied by a matrix susceptible of polish. In one portion of a femur of *Par. bombidens* the looser osseous tissue had so far decomposed that the invading matrix simulated the appearance of a large medullary cavity; but this showed instructive evidence here and there of osseous tissue, and presented no boundary such as is shown in *Platypodosaurus*, where the true narrow cylinder is as well defined as in *Ornithorynchus* and *Echidna* (fig. 9 *a*), though of less relative size.

The fossil femur on which the reptilian genus *Euskelesaurus*, Huxley, is founded is stated to show "a large and distinct medullary cavity"†.

The chief characteristic of the femur of *Platypodosaurus* is the

* *Loc. cit.* specimen No. S. A. 28.
† Quarterly Journal of the Geological Society, vol. xxiii. (1866) p. 2.



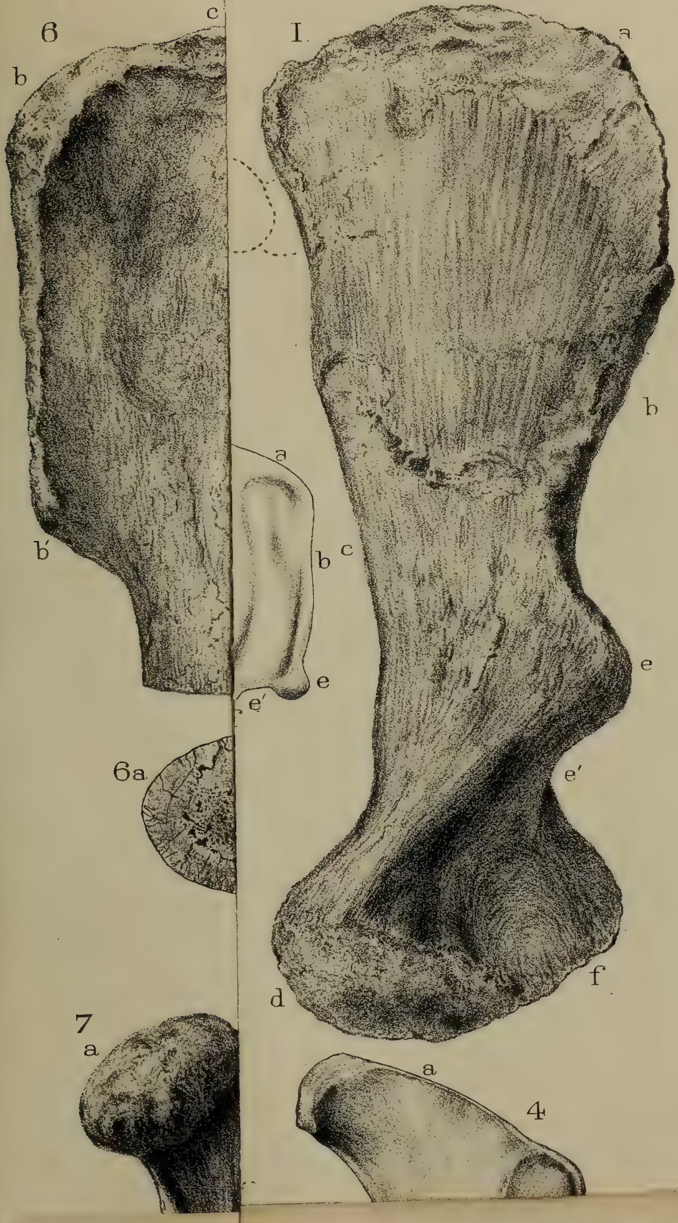
A. S. Foord. del et lith.

Mintern Bros. imp.

A S Foord del et lith.

PLATYPODOSAURUS

Mintern Bros imp


6
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PLATYPODOSAURUS.

S Foord del et lith

Mintern Bros imp

longitudinal extent and well-defined ridge-like form of the great trochanter, in which, as in the proportions of breadth and fore-and-aft compression of the proximal (probably) half of the bone, I find the closest agreement in the femur (Pl. XVII. fig. 9) of the Spiny Monotreme (*Echidna hystrix*).

From the number of correspondences presented by parts of the skeleton of *Platypodosaurus* with homologous ones in the skeletons of the two existing genera of Monotrematous Mammals, one is led to relieve the dry work of comparison by speculations on the vast number and variety in gradually advancing structure of air-breathing vertebrates, offsprings of the strange reptilian forms exemplified by their remains in Cape localities—but which, of old, may have spread over lands extending thence northward and eastward, now in great part submerged, and of whose inhabitants a remnant still survives and lurks in the burrows and waters of Australia. One may also conjecture, on the derivative hypothesis, that the higher class of Vertebrates, as represented by the low ovoviviparous group now limited to Australasia, may have branched off from a family of Triassic Reptilia represented, and at present known only, by the fragmentary evidences of such extinct kinds as that which forms the subject of the present communication. But this is far from being the only instance of correspondences between organisms, both animal and vegetable, of the Cape of Good Hope and those of New Guinea, Australia, and Tasmania.

The European Triassic reptile *Placodus*, nearest akin to the Cape *Endothiodon*, has the molar dentition of each mandibular ramus represented in one species by two low, broad, subquadrate plates which overhang the border of the bone (Pl. XVII. fig. 11). In the young *Ornithorhynchus* the molar dentition of each mandibular ramus is represented by two similar plates, which in the adult become confluent, also overhanging the supporting bone, and still indicating their primitive separation (ib. fig. 10). True it is they are not calcified in the duck-mole; but, in other more significant characters, this mammal alone repeats the Placodont ones. I may add that the rami of the mandible in both divaricate anterior to the symphysis, as in figs. 10 & 11, Pl. XVII.

The fossils of *Platypodosaurus* which have afforded the foregoing descriptions were obtained by E. J. Dunn, Esq., of Oaklands, Claremont, Cape of Good Hope, from a quartzose Karoo formation 3500 feet above the sea-level, near Graaff Reinet, and were transmitted as a donation to the British Museum.

Postscript (British Museum, 22nd June, 1880).—I have received this day a copy of a "Second Contribution to the History of the Vertebrata of the Permian Formations of Texas," by E. D. Cope (read before the American Philosophical Society, May 7th, 1880). In this paper the Author states:—"The order *Theromorpha* approximates the *Mammalia* more closely than any other division of *Reptilia*. This approximation is seen in the scapular arch and humerus, which nearly resemble those of the *Monotremata*, especially *Echidna*, and in the pelvic arch, which Owen has shown, in the suborder *Anomodontia*, to resemble that of the Mammals, and, as I have pointed out, especially that of *Echidna*" (p. 1).

In the pelvis of *Dicynodon tigriceps*, described and figured in my 'Descriptive and Illustrated Catalogue of the Fossil Reptilia of South Africa'*, the sacrum includes six ankylosed vertebræ, and the expanse of the iliac bones resembles that in many placental mammals; whereas in *Echidna* the ilia are strong but narrow three-sided columns, and the sacral vertebræ are but three in number. The chief pelvic characteristic in that Monotreme is in the marsupial bones, which exceed the ilia in length. I have not detected any evidence of these bones in the South-African reptilian fossils which I have hitherto examined. The particulars of the monotrematous characters of the scapular arch and humerus are not given; nor are any figures of the subjects of Professor Cope's paper appended thereto; but the author states (p. 22) "that they will appear in the Proceedings of the American Philosophical Society." The discovery of the fossil marsupial bones in the pelvis of the Permian Reptile will be one of much interest.

EXPLANATION OF PLATES XVI. & XVII.

Plate XVI.

Platypodosaurus robustus.

Fig. 1. Two dorsal vertebræ, vertically and longitudinally bisected, in outline: $\frac{2}{3}$ natural size.
2. Transverse vertical section of middle of centrum, in outline: $\frac{2}{3}$ nat. size.
3. Side view of a dorsal vertebra: $\frac{2}{3}$ nat. size.
4. Vertical longitudinal section of two dorsal vertebræ of *Echidna hystrix*: nat. size.
5. Foremost sterneber: $\frac{1}{2}$ nat. size. *a'*, anterior articular surface; *b'*, lateral articular surface; *c'*, posterior articular surface.
6. Sternum of *Ornithorhynchus paradoxus*: nat. size. *a*, *a'*, anterior articular surface; *b*, *b'*, lateral articular surface; *c*, *c'*, posterior articular surface.
7. Humerus; rather more than $\frac{1}{2}$ nat. size.
8. Humerus of *Ornithorhynchus paradoxus*: nat. size.
9. Humerus of *Echidna hystrix*: nat. size.

Plate XVII.

Fig. 1. Scapula of *Platypodosaurus*, outer surface: $\frac{1}{2}$ nat. size.
2. Scapula of *Platypodosaurus*, inner surface: $\frac{1}{2}$ nat. size.
3. Scapula of *Ornithorhynchus paradoxus*, outer surface: nat. size.
4. Scapula of *Echidna hystrix*, outer surface: nat. size.
5. Digital bones of the fore paw of *Dicynodon* (?), outer surface: nat. size.
6. Proximal part of femur of *Platypodosaurus*, front surface; 6 *a*. Transverse section of shaft of the same: $\frac{1}{2}$ nat. size.
7. Proximal part of femur of *Platypodosaurus*, inner border: $\frac{1}{2}$ nat. size.
8. Proximal part of femur of *Pareiasaurus*, front surface; 8 *a*. Transverse section of shaft of the same: $\frac{1}{4}$ nat. size.
9. Femur of *Echidna hystrix*, front surface; 9 *a*. Transverse section of shaft of the same: nat. size.
9'. Femur of *Echidna hystrix*, inner border: nat. size.
10. Portion of right mandibular ramus and molar teeth of *Ornithorhynchus paradoxus*: nat. size.
11. Portion of right mandibular ramus and molar teeth of *Placodus Meyeri*: $\frac{1}{2}$ nat. size.

* 4to, 1876, pp. 40, 41, pls. xxxvi. & xxxvii.

Discussion.

Prof. Seeley, after having had the opportunity of inspecting the specimens, by the courtesy of Prof. Owen, had arrived at the same conclusions with the author as to the distinctness of this form. He was not able to follow the author in dividing the reptiles of South Africa into Dinosauria, Anomodontia, and Theriodontia, and asked Prof. Owen to state how these groups differ in vertebral characters, that we might judge of the affinities of the fossil. All seemed to him to show remarkable mammalian resemblances, as had been pointed out by the author; but he doubted whether this implied the evolution of Mammalian orders from the South-African reptiles, as Prof. Owen had suggested. He alluded to the remarkable modification of the humerus found in the Mole, as throwing light on the singular modifications of form which may result from burrowing-habits; and suggested that, as the *Ornithorhynchus* also burrows and its resemblances to the fossil do not extend to the more important parts of the skeleton, the correspondence was more likely to show merely that the humeral bones were used in similar ways in the fossil reptile.

Prof. Owen stated that the orders of the fossil reptiles which he had established were distinguished by characters as well marked as those which separate some of the orders of living Reptilia. In reply to Prof. Seeley he pointed out that the form of the phalanges in the form he described are those which belong to omnivorous forms like the Anomodonts, and not to carnivorous forms like the Theriodonts.

32. *On certain* Geological Facts *witnessed in* Natal *and the* Border Countries *during nineteen Years' Residence.* By the Rev. George Blencowe. Communicated by Rev. Henry Griffith, F.G.S. (Read November 19, 1879.)

The basal strata of Natal as seen on the coast are shales, which are succeeded by sandstones of various kinds for from twenty to twenty-five miles into the interior, after which, about the same distance of hard shale occurs in deep beds. The valley of the Umgeni seems to have been formed by subsidence, as the sandstone hills in the neighbourhood are greatly cross-fractured, and the beds dip with an inclination nearly corresponding to the surface-curve. This also is the case with other, shallower valleys in the neighbourhood. There are also, on the upper edge of the northern side of the Umgeni valley, cliffs, from which the front has fallen away, which are without a dip, as also in several other cases in the vicinity where the original level has been maintained, the edge of which presents a perpendicular cliff.

In the northern and north-western portion of Natal a white sandstone prevails, which increases in the thickness and hardness of the strata as we ascend. This part is a succession of irregular ridges and truncated cones in every variety of relative position. The present configuration seems to have arisen from denudation, as the sandstone of the remaining hills is horizontal and without cross-fracture. There is also a high plateau, known as the Biggars-Berg, about 50 miles long, which corresponds in structure and height with the highest of the remaining hills, and appears to be the only part which has been free from the denuding force which has scooped out the valleys and abraded the hills around. The substance of this plateau is sandstone, in strata from 3 to 20 feet thick; and it has a capping of trap, which is generally basaltic, and from 20 to 100 feet thick, while the average height above the surrounding valleys is about 1000 feet. The surrounding valleys are thickly strewn with broken-up trap of sharp angularity, which forbids the supposition that the fragments have been brought by a stream from a distance, but implies that they are near where they first fell.

In this district of horizontal sandstone the coal of this part of South Africa is found; and the seams reach from a few miles to the north of Ladysmith to the edge of the mountains in the Lydenburg district of the Transvaal, and east and west from near Rorke's Drift to a few miles east of the junction of the Mooi river with the Vaal. There has been no search for coal; and it is only known where it has been casually seen in the face of a cliff or in the bottom of a water-course. On the Dundee and adjoining farm, there is one seam 10 feet thick; and about a quarter of a mile further up, at a perpendicular height of from 15 to 20 feet above, there are three more of only a few inches, between which are interposed equally thin strata of sandstone; and a third of a mile yet further up there is another seam of coal 7 feet thick, and less than 20 feet in perpendicular height above the three. Seven miles west-by-north from Rorke's Drift, there is a seam 3 feet thick; and a mile south in horizontal distance, and 800 feet above it, is another of the same size; while a mile and a half north-west occurs a third, about 1000 feet above the first.

In nearly all the lower strata of these sandstones occur circular holes with perpendicular sides, going through the stratum in which they are found. Generally they are from 8 to 14 inches in diameter; and in a ford of the Ingoko river they occupy more than half of the horizontal surface; but this is a special case. On the farm Dundee, there is one 3 feet in diameter which passes through a stratum of from 25 to 30 feet. These holes seem to have been occasioned by deposits of sand around the trunks of trees, which now occasionally occur to the depth of from 2 to 5 feet in one rain. The thick strata of these sandstones, from their homogeneous continuity, seem to have been deposited at one time, whereas in the smaller basal strata something like lamination can be detected, and occasionally wave-prints, neither of which have I seen in strata of 20 feet or more. It also sometimes happens that a very hard stratum rests on one which is so soft that the atmosphere corrodes the face, while the rain finds its way through the fissures of the superincumbent strata, and washes out large caves.

One spur of the Biggars-Berg terminates about a mile from Rorke's House, which stands in a denuded hollow, with an isolated hill of the same structure as the Biggars-Berg at the back, having all its sides but one greatly abraded. Isandhlwana is about two miles to the east of the last-mentioned hill, and is the final one in that direction which stands forth with perpendicular sides revealing its structure, while its irregular grass-covered trap capping presents the appearance of a couchant lion, as if keeping guard over the stony frontier. About two miles below Isandhlwana, immediately below the place where the few who escaped crossed the Buffalo, half the river-bed is cut out of a solid mass of trap, not columnar, and which has been deposited on its present irregular bed, as shown by a curve of diverse grain and colour on its perpendicular face. This is about 1500 feet below the basaltic capping of Isandhlwana. There are several other deposits of trap at this lower level within a mile and a half, those near the mouth of the Isibindi partly basaltic, and in a valley immediately to the west of the Buffalo in horizontal slabs.

In crossing the Tugela by the Greytown and Biggars-Berg road, we ascend a valley on the Biggars-Berg side which for a distance of three miles and an aggregate depth of 500 feet has been washed out of brown, blue, and black shales of fine lamination, and exceedingly friable; and near the termination of the shale the Umsinga Mountain rises from its foot to more than 1500 feet. But just at its present foot a mass of basaltic trap is found resting on the shale, and bounded on all sides but its perpendicular face by the sandstone and shale of the Umsinga and an adjoining denuded ridge. The distance from the top of this isolated mass of trap to the base of the trap capping of the Umsinga is not less than 1000 feet, and the horizontal distance is not more than a third of a mile. The surrounding strata, so far as seen, are undisturbed.

The peculiar feature of the geology of the Orange Free State at its line of junction with Natal is the existence of isolated mountains of sandstone and trap, which rise to an average height of 2000 feet from the present general level, and which, from their sameness of structure, evidently at one time formed parts of a continuous line of country of the same elevation. Through the whole of this line there is no evidence of volcanic eruption by which the trap has been thrown up, nor is there present indication of the abrading force by which the intervening mass of trap and sandstone has been carried away.

In the south-western part of the Transvaal, near Potchefstroom, occur rounded hills of a creamy white stone, with small red specks like oxide of iron: it is of very fine granulation, dense and opaque. It is not lime, and cannot be described as quartzose.

In the central portion of the Transvaal, the Magaliesberg runs east and west about 70 miles. This range is a series of sandstone upheavals presenting a face from 400 to 700 feet deep, with a back slope of several miles. In some cases the sandstone in this range is in a quartzose condition.

About 30 miles to the north-east of the Magaliesberg we enter on the large metallic deposits which are the distinguishing mark of this part of the Transvaal. Mountains of very rich iron-ore succeed each other up to the Gold-fields, near to which hæmatite abounds in horizontal slabs and nearly perpendicular ridges.

Pilgrim's Rest, the most extensive and richest Gold-field yet wrought, is a gorge running at right angles to the Blyde river, in an easterly direction, at an average depth of 1000 feet. The tops of its undenuded sides are covered with lava; all the gold found in it is molten; and calcined quartz to a depth of 18 inches covers the original bottom and sides of the excavation, except in the course of a stream which at some former period has poured with great violence through the gorge, so as to round the blocks of lava with which its bed was covered.

Immediately over the ridge, at the eastern end of Pilgrim's Rest, the Mac-Mac diggings are found, where the violent aqueous and igneous actions just referred to have not prevailed. There is not the capping of lava to the hills; and the gold found here is bright and angular, as though it had just fallen from its quartz matrix.

Discussion.

Prof. T. Rupert Jones said that although much was yet to be learned about the district, large areas had been already examined, and the paper added something to our knowledge, though several of the phenomena mentioned in it had been previously described. He made some remarks on the coal formation of the Stormberg and Natal.

33. Note *on the Occurrence of a* new Species *of* Iguanodon *in a Brick-pit of the* Kimmeridge Clay *at* Cumnor Hurst, *three miles W.S.W. of Oxford.* By Prof. J. Prestwich, M.A., F.R.S., F.G.S. (Read April 28, 1880.)

The fact of this discovery was briefly announced in the Geological Magazine for May 1879 *. Since then the further progress of the works has made clearer the position of the seam in which the bones were found, and shown more exactly its relation to the mass of the Kimmeridge Clay and to the overlying Lower Greensand, about which some doubt was expressed at the time. This and the many fossils now obtained from the *Iguanodon*-seam must remove all such doubt.

The pit is situated to the left of the road leading from Oxford to Cumnor, at the foot of an outlying mass of Lower Greensand, forming a conspicuous and isolated hill rising to the height of about 500 feet. The Kimmeridge Clay here immediately underlies the Lower Greensand, without the intervention of the Portland beds (which are present on the other side of the Thames valley at Shotover), and rests upon the Coral Rag, which crops out at a distance of a few hundred yards both to the eastward and westward of the pit.

A tramway driven into the side of the hill led to the discovery of the bones in a thin sandy seam intercalated in the clay, and, at the point where discovered, about 4 feet deep beneath the surface.

The prolongation of the tramway, however, has now shown that the sandy seam runs into the hill, dipping at an angle of from 3° to 4°; and by following up the beds till they pass under the Lower Greensand, it is evident that the zone to which the *Iguanodon* belongs is about 34 feet beneath those sands. The following is a section of the pit as it is now opened out in a length of 340 ft. :—

Section at Cumnor Hurst.

* During my absence from Oxford in the Easter of that year, a workman took a bagful of bones to Dr. Rolleston, who, perceiving their importance, kindly secured them for the geological department. Every facility has been afforded me, both by the owner and the manager of the works, to follow up this interesting discovery; and with the aid of my assistant, Hy. Caudel, a large portion of the skeleton has now been recovered.

	ft.	in.	
1. Coarse ferruginous sands and grit without fossils	10	0	1. *Lower Greensand.*
a. Light-coloured clay	2	0	2. *Kimmeridge Clay.*
b. Dark grey clay with numerous layers of small ferruginous and calcareous nodules and a layer of large tabular Septaria, few fossils ...	18	0	
c. Clay with band of fossils	14	0	
d. Seam of clay laminated with white sand, *Iguanodon*-bed	0	3	
e. Clay with large Septaria, lower down	4	+	

There is reason to suppose that the entire skeleton of the *Iguanodon* was lying in a position across the driftway, in the thin but conspicuous seam of clayey sand *d*; but it was not until the removal of great part of the clay that attention was directed to it, and it was with difficulty that many of the bones were afterwards recovered. Unfortunately, the bones of the head suffered much in the removal, and have been in great part lost; but the vertebræ and limb-bones, which are harder and more compact, are but little damaged, and have been in great part recovered.

Owing to the sandy and porous nature of the seam, the shells found in it were mostly decomposed and difficult to recognize. One very characteristic shell of the Kimmeridge Clay, although rare in the Oxford district, occurs here in profusion, viz. *Gryphæa virgula*; with these have been found small species of *Astarte* and *Pleurotomaria*, a *Trigonia*, with specimens of *Trigonellites latus*, and *Lingula ovalis*.

From the clay (*e*) below I have obtained *Lucina lineata*, *Ichthyosaurus* (vertebræ and portion of ribs), *Pliosaurus*, *Dakosaurus* (1 tooth); while the clay above (*c*) is rich in the ordinary fossils of the Kimmeridge Clay, as the following list will show:—

Astarte.
Cardium striatulum.
Lima.
Modiola bipartita.
Myacites recurvus.
Pecten nitescens.
Perna mytiloides.
Pinna lanceolata.
Thracia depress.
Trigonia gibbosa.
Pleurotomaria reticulata.
Ammonites biplex.
Serpula tetragona.
Vertebræ of Plesiosaurus.

In the upper bed of clay (*b*) *Ammonites biplex* is tolerably common also; but the other fossils are not so numerous. It would appear therefore that the horizon on which the *Iguanodon* occurred is in the upper part of the Kimmeridge Clay of this district. It is here greatly reduced from the great development it has south in Dorsetshire; for at Cumnor its total thickness cannot exceed from 70 to 80 feet. Largely as the Kimmeridge Clay is worked elsewhere in the neighbourhood of Oxford, not a single bone of *Iguanodon* has hitherto been found in it; nor have the remains of *Iguanodon* been found elsewhere lower in the geological series than the Lower Greensand and Wealden strata of Kent and Sussex.

One other instance, however, has recently came to my knowledge of the occurrence of *Iguanodon* in the Oxford district. In the fine collection of fossils from the Lower Greensand of Faringdon, made by Mr. Davey, of Wantage, and now in the Oxford Museum, there are two teeth of *Iguanodon*; but whether they belong to the Lower Greensand, or whether they are to be classed with the numerous derived fossils found in those beds, it is difficult to say. As, however, they are not much worn, they may be of Lower-Greensand age.

The presence of drifted wood and of the *Iguanodon* in the Kimmeridge Clay of this district, and of large Dinosaurs at Swindon, together with the great thinning of this formation as it trends to the south-west, render it probable that land in that direction was not far distant, and that that land may have been the same as that of the proximity of which we have more distinct evidence in the many quartz, slate, and metamorphic rock-pebbles present in the Lower Greensand of Faringdon, a deposit evidently formed near an old shore. This land, since submerged and covered by upper Cretaceous strata, was in all probability the prolongation of the old axis of the Mendip and Ardennes, the elevation of which took place in Permian or Triassic times.

My friend Mr. Hulke has kindly taken charge of this Kimmeridge *Iguanodon*; and in his hands I feel sure that its structural peculiarities and relationship will be accurately determined and established.

(For Discussion see page 456.)

34. Iguanodon Prestwichii, *a new Species from the* Kimmeridge Clay, *distinguished from* I. Mantelli *of the Wealden Formation in the S.E. of England and Isle of Wight by Differences in the Shape of the Vertebral Centra, by fewer than five Sacral Vertebræ, by the simpler Character of its Tooth-serrature, &c., founded on numerous fossil remains lately discovered at* Cumnor, *near Oxford.* By J. W. Hulke, Esq., F.R.S., F.G.S. (Read April 28, 1880.)

[Plates XVIII.–XX.]

These fossils, which Mr. Prestwich has kindly given me an opportunity of studying, are, for the extent of information they convey of nearly every part of the skeleton, the most important Iguanodont remains yet discovered at any one time in this country. The only others that may vie with them are those in the well-known Mantellian Maidstone block, in the British Museum, and some, said to represent the greater part of a skeleton, reported to have been found several years since at Hastings, preserved in a private collection, inaccessible, which in their entirety have not, so far as I can learn, ever been examined by an anatomist.

The Cumnor fossils appear to have formed part of one skeleton. They represent an animal between 10 and 12 feet long, which had not reached maturity. Its head was lizard-like, with large eyes and capacious nostrils. Its neck was very flexible and moderately long. Its trunk, particularly the thoracic region, was long, and borne on stout clawed limbs, of which the hinder were much stouter than the fore. The tail, of considerable length, tapered very gradually; and for more than half its length it was flattened laterally.

Unfortunately, as too frequently happens, the removal of the fossils by the unskilful hands of day-labourers has occasioned much damage and many losses. The bones had been already much crushed by the pressure of the beds; but many of the fractures are plainly quite recent. These injuries are not, however, without some compensating circumstances; for the broken surfaces afford in several instances an insight into structural details which may not be so well perceived in an entire bone. This is especially exemplified in the remains of the head, in which the persistence of the sutures and the broken surfaces discover structural details not to be seen in the skull of an old Iguanodon from Brooke, Isle of Wight, which I brought under the notice of the Geological Society in 1870, and which till very recently was the only fragment of an Iguanodon skull which had been identified and described. Taken together, the Cumnor and Brooke skulls give a nearly complete anatomy of this part. The Iguanodont dentition, particularly the maxillary, has never been so well shown as by these Cumnor fossils. I may instance also, as matters in which they have proved highly instructive, the variations of the form of the articular surfaces, and also of the length of the vertebral centra in different regions of the column, and the structure of the tarsus.

A conviction of the value of this skeleton for future reference has led me to describe with greater detail than would otherwise have appeared necessary all the more important and better-preserved bones.

Head (Pl. XVIII.).—This has been much crushed and broken. The most instructive pieces preserved are:—I. 1*, the basis cranii as far forward as the hypophysial fossa; I. 9, the back of the skull, and the sides nearly to the same extent as the base; I. 10, the frontal region; I. 3, 4, 8, parts of both mandibular rami; and I. 2, 5, 6, 7, portions of both maxillæ.

I. 1 (Pl. XVIII. fig. 3).—The occipital condyle has a reniform outline. Its horizontal diameter is 29 millims., and its vertical diameter 19 millims.; these figures, however, do not convey a correct idea of the extent of the articular surface in these directions, which is greater vertically than horizontally, an arrangement manifestly associated with greater angular mobility of the head up and down than from side to side at the occipito-atlantal joints. The condyle is composed mainly of the basioccipital bone; and only a small part at its upper lateral corners is contributed by the exoccipitals. At the under surface a well-marked constriction or neck separates the condyle from a pair of blunt pyramidal swellings, divergent downward extensions of the basisphenoid, corresponding in position to the posterior pair of similarly placed processes in extant lizards. Against these basisphenoidal swellings laterally the neck of the basioccipital expanding abuts, whilst mesially it sends downwards and forwards a short triangular process which is wedged in between them. This intercalated basioccipital process has a low but sharp median crest, which begins behind in a small pit, pierced by vascular foramina lying in front of the condyle.

When the front of the fossil is viewed there are apparent, 1st, below, in the middle line, a rough broken spot, about 12 millims. in diameter, where the præsphenoid has been split off; 2nd, above this a smooth vertical groove, ending above in the floor of the cranial cavity—it is obviously the posterior half of the hypophysial pit; 3rd, on each side of this an uneven fractured boss, the junction of ali- and basisphenoids. Each of these bosses overhangs the smooth antero-lateral surface of the descending basisphenoidal process of its own side; and there is immediately beneath it a winding groove, which rises from the undersurface of the skull through the hypophysial fossa into the cranial cavity; it marks the course of the internal carotid artery. A branch of this groove, ascending in a backward direction, enters the skull through the principal foramen of exit for the 5th nerve.

Pl. XVIII. fig. 4. The upper surface of the fragment exhibits (1) a mesial trough, the floor of the skull-chamber. This is 7·5 millims. wide near the foramen magnum; and here it is relatively deep. Anteriorly it widens through a space of 26 millims., and then deepening

* These numbers refer to labels attached to the bones.

forms a wide depression behind the hypophysial pit. Throughout this extent, 38·5 millims., the floor of the skull-chamber consists of a continuous unbroken piece, basioccipital, which ends taperingly in the depression behind the sella turcica, where the basisphenoid comes into view. Thus the basioccipital overlaps the basisphenoid on the upper as also at the under surface of the basis cranii.

Laterally the persistence of the sutures and the foramina of exit for the cranial nerves makes it possible to recognize in sequence from behind forwards (1) a stout exoccipital, articulating with the basioccipital by a broad serrated suture, and perforated at 10 millims. from the foramen magnum by an aperture (for 9th nerve?). At 6 millims. in front of this opening is another groove (for transmission of vagus?), which appears to pass out between the exoccipital and opisthotic elements. This, again, is followed by a very conspicuous groove, situated where the basioccipital attains its greatest breadth in the floor of the skull-chamber. In front of this, where the prootic might be expected, is the upper opening of a deep funnel-like pit, which descends within the bone into the basisphenoidal process visible at the under surface of the skull. The form of this pit does not suggest the transmission of blood-vessel or nerve, whilst its situation hints that it may be part of the auditory apparatus, possibly an air-channel connected with the middle ear. The fact that in old Iguanodons the inferior basisphenoidal processes are hollow sinuses * favours this conjecture. A wide groove, presumably for the 3rd nerve, separates the prootic and alisphenoid.

Pl. XVIII. fig. 5. Another fragment (I. 9) comprises the back of the skull and the sides nearly to the extent of the piece just described. The supraoccipital bone contributes the upper boundary of the foramen magnum, as in extant lizards. It is not excluded from this opening as in crocodiles—a point worthy of notice, because the general form of the occiput, so far as it can be recognized in this fossil, has a crocodilian likeness, as has also the occiput in my Brooke Iguanodon-skull. Immediately above the foramen magnum the supraoccipital stretches laterally outwards to what are apparently the roots of a stout suspensorium (for the attachment of the quadrate bone), now broken off and missing. This is a strong pyramidal projection, below constructed of the blended exoccipital and opisthotic, above of another and distinct part, parietal. Between these two parts of the suspensorium the broken surfaces show that an extreme lateral extension of the supraoccipital intrudes. Nearly at its mid-height this bone abruptly contracts to less than half its breadth below (22·5 millims), being here encroached on and overlapped by the suspensorial extension of the parietal. This narrowing of the supraoccipital is too symmetrical to be altogether due to the downward crushing of the parietal upon it; it has doubtless been increased by this, but is a natural conformation. The upper border of the supraoccipital is a smooth edge, which was connected with

* I learned this many years ago in a fragment of a very large old skull in the collection of the Rev. W. Fox.

the parietal by sutura harmonia. In their present mutilated state the back and sides of the skull form a rude pyramid, of which the base of the posterior face is notched by the foramen magnum, and the postero-external angle is formed by the truncated suspensorium.

The lower borders of the fragment correspond to the upper borders of the basis cranii. They, as also the inner surface, are too mutilated for description.

On the under surface of the base of the right suspensorium is a wide groove, directed forwards and inwards. It exactly corresponds to the groove in the Brooke skull to which I lately referred, and may have lodged the stapedial rod.

Pl. XVIII. figs. 1, 2. A third fragment of the skull (No. I. 10) comprises parts of the parietal and frontal regions and of the left temporal bar. The parietal bone is single; no trace of mesial suture joining two halves is discernible. This is mentioned because in the nearly allied *Hypsilophodon* such a suture has been thought to exist. The sides of the parietal fall off steeply from a sharp median crest, which divides in front, and, bending outwards, here forms the anterior boundary of the upper temporal opening. There is no parietal foramen.

The frontal is a very large bone. Its length contrasts strongly with the shortness of the parietal; and its breadth also is considerable. It consists of two halves, united by a very evident mesial suture. Its structure is very dense, without diploë. Deep sutural indentations in its right border show that the præ- and postfrontal bones approached each other very closely, and that the frontal formed but a small part, if any, of the upper border of the orbital opening. The direction of this opening is lateral, as in *Hypsilophodon Foxii*. The postfrontal bone, of which part is preserved on the left side, is large; its smooth orbital surface is of great extent; a long slender branch separated the orbital from the lateral opening; and a stronger branch directed backwards forms the anterior part of an upper temporal bar.

In the undersurface of the fossil are shown:—1st. A large lozenge-shaped mesial hollow—the vaulted inner surface of the skull—narrow behind, in its longer diameter sinuous, being convex in the parietal part and concave in the frontal. Its greatest width coincides with the parieto-frontal suture. It narrows anteriorly at a line drawn through the middle of the orbital surfaces; and in front of this it expands for the reception of the olfactory lobes, which must have been of large size—an inference confirmed by the large size of the nasal chambers, indicated by the great size of the nasal bones. 2nd. Laterally, on each side of the vault of the skull-chamber is the smooth orbital surface lately mentioned. Its outline is roughly rhomboidal. The two outer sides are sutural, as already mentioned, and afforded attachment to the præ- and postfrontal bones. The inner angle is rounded off, and the two inner sides make a continuous curve. Of this the posterior $\frac{3}{4}$ are broad and rough as if sutural, and the anterior $\frac{1}{4}$ is a thin, smooth, free crest.

Jaws.—Other very instructive pieces are fragments of both maxillæ and of both rami of the mandible. Of the maxillary fragments, No. I. 2 is the most important. Its outer alveolar border, 77 millims. long, has in this space the sockets of 9 teeth. Immediately above this free border the bone rapidly swells, acquiring greater bulk mainly by expansion of the outer wall, which in its ascent slants outwards as high as the level of the upper ends of the tooth-fangs, above which it again falls inwards towards the mesial line. The inner dentary wall, a thin plate, rises nearly vertically as high as the tops of the tooth-fangs, above which it bends outwards, and joins the outer wall of the bone.

Above the alveolar border the outer surface of the maxilla is pierced by a row of conspicuous foramina, as in *Megalosaurus* and *Teratosaurus.*

Viewed from above, this piece of the upper jaw shows at the inner side the smooth surface overlying the ends of the tooth-fangs, and outside this a broken edge. Nearly in the middle of this edge, sunken in the substance of the base, outside the tooth-fangs, is a remarkable oval pit, 13 × 7 millims. across at its mouth, and 7 millims. deep. Its surface is perfectly smooth. The outer margin of this pit is a thin smooth lip, which apparently formed the lower border of a conjugate anteorbital foramen. Behind, at its inner side in the dry skull, the pit seems to have freely communicated with the naso-buccal cavities. Behind the pit is a narrow groove, of which the outer border is a thin natural edge. I am disposed to view this as the sutural groove for the reception of the front margin of the jugal bone, which fixes this as the hinder part of the jaw, and shows it to belong to the left side. In front of the pit is another, wider groove, the significance of which is less obvious. In the piece No. I. 5, the corresponding part of the right maxilla, this groove descends from the pit forwards in the substance of the jaw outside the teeth. Near its origin it is joined by a lesser channel, which begins not far from the jugal groove near the back of the jaw, and passes forward skirting the inner border of the pit. Do this pit and the wide groove proceeding from it represent the glandular grooves which tunnel the hinder part of the maxilla in the crocodile? May the lesser groove have transmitted a branch of the 5th nerve? Less imperfect materials must answer these questions.

The fossils No. I. 3, 4, are considerable portions of the mandibular rami. They have the well-known Iguanodont form, and do not need particular description.

Dentition.—In every piece of maxilla or mandible holding teeth, the crowns of all which were in full wear at the animal's death have been broken off and lost; in most instances this damage is quite recent; but their fangs and the germs of many successional teeth remain, and these afford very complete information respecting the perfect form of the mature upper and lower teeth, and also of the manner of succession.

The crown has the compressed, ridged, serrate form characteristic of the family Iguanodontidæ.

Upper Teeth (Pl. XVIII. fig. 7).—The crowns of these are narrower in the antero-posterior direction, and the primary ridge in their outer stoutly enamelled surface is stronger than in the lower teeth, characters noticed by Melville, Mantell, and also by Owen, which may serve to distinguish these teeth when detached from the jaw. This ridge divides the outer strongly enamelled surface unequally, being much nearer to the anterior margin. At the free end of the unworn crown it ends angularly at the meeting of the anterior and posterior borders. Of these the former is nearly straight, whilst the latter bends towards the angle in a full sweep. The most prominent part of the ridge is nearly at the mid-length of the crown, and from here it declines towards a cingulum, which marks off the crown from the fang. The outer surface between the primary ridge and the front straighter border of the crown has the form of a wide, deep, smooth groove, whilst the space between it and the distant posterior curved border is sculptured by several minor longitudinal ridges, which start from the minuter cusps of the terminal serrature, and are separated from one another by narrow grooves. These secondary ridges are fewer, and the grooves between them narrower towards the middle of the crown, and they subside towards the cingulum. The serrature is limited to the free end and the front and posterior border of the distal half of the crown. In the half next the fang these borders are smooth uninterrupted ridges. The cingulum is a sinuous inconspicuous line crossing the outer surface of the tooth in a double curve, the two ends of which are convex towards the fang. One of these corresponds to the basal end of the primary ridge; and the other is nearer the distant border of the crown. The cusp between the curves is nearly equidistant from the two borders, but slightly nearer the primary ridge. In a tooth which has descended so far beyond the outer alveolar border that the cingulum is 5·5 to 6 millims. distant from it (No. 5 in I. 2, fig. 7), the outer surface of the exposed part of the fang is covered by wavy lines. The inner surface of the crown is gently convex, smooth, and even, and unsculptured, the terminal marginal serration being scarcely prolonged upon it. In a favourable light faint transverse markings are apparent on it. A longitudinal swelling subdivides this surface unequally; the correspondence of its position to that of the primary ridge on the outer surface makes this the thickest part of the crown.

The lower teeth (Pl. XVIII. fig. 6) have much broader crowns than the upper. In the angulation of the hinder margin of the crown, the curve and greater length of the anterior margin, the unequal division of the thickly enamelled inner surface by a primary ridge, they prefigure the teeth of Iguanodon from the Wealden-beds in S.E. England and the Isle of Wight. They differ, however, from these in one detail, the character of the serrature. The free edge of the small plate-like cusps of this is in such Wealden teeth minutely mamillated; but in these Cumnor teeth the margin of the lamella is even. I found this difference in teeth of very nearly the same size. Perhaps in relative simplicity of sculpturing the Cumnor Iguanodon's teeth more closely resemble the teeth in the dentary piece of a mandible obtained from near the horizon of the Purbeck cinder-bed at Swanage, figured by Prof. Owen in Foss. Rept. Wealden and Purbeck Formations, Suppl. v. pl. i. (1874).

Several broken teeth show that both upper and lower teeth have a large pulp-cavity (Pl. XVIII. fig. 8). It is now filled with calcite, which, by its whiteness, contrasts strongly with the dark dental tissues. The cavity passes far into the crown, towards the base of which it is widest; and it contracts greatly towards the end of the fang, which it pierces as a minute inconspicuous pore. The fang in both jaws tapers to a point. I particularly mention this because, though known and described already, it has been lately asserted that such tapering ending of the fang, with accompanying reduction of its pulp-cavity almost to its obliteration, is unusual in *Iguanodon Mantelli*.

Succession.—The replacement of older teeth as their crowns are worn out, by germs developed in reserve cavities lying nearer the inner surface of the jaw, is more completely illustrated by these Cumnor fossils than by any which had previously come under my notice. Four successional phases of upper and lower teeth are apparent. In the maxilla, I. 2, may be seen:—1, stumps ready to be shed, as that marked No. 5, where the cingulum is 5·5 to 6 millims. beyond the outer alveolar border; 2, teeth the crowns of which were in full use, as that marked No. 4, where the entire crown has emerged, the cingulum lying nearly in the plane of the alveolar margin; 3, germ-crowns, which have emerged only $\frac{1}{2}$ or $\frac{1}{3}$, and had not come into use, as Nos. 1, 3, 10, 12, 14; 4, quite small germ-crowns, which only just peep over the inner parapet. In these four phases the younger lie inside the older teeth, alternating with them, the arrangement being such that, when one of the oldest teeth is ready to fall out, a fully formed successional tooth moves outwards into its place.

The fragment of lower jaw, I. 3 (fig. 6), illustrates for the lower teeth, even more beautifully, the same four phases, the same grouping and progression. Nos. 1, 3, 5, are teeth nearly worn out; Nos. 2, 4, 6, teeth in full use; Nos. 7, 8, 9, crowns scarcely half emerged; and Nos. 10, 11, minute germs only just visible above the inner parapet.

An idea of the size of the teeth may be gleaned from the following measurements. The maxillary piece, I. 2, in a space of 75 millims, contains the sockets of an outer series of 9 teeth. The breadth (*i. e.* antero-posterior dimension) of a fully formed upper crown is 9·5 millims.; the length of a fang (I. 5) is 20·5 millims. The dentary part of the left mandibular ramus, I. 4, in the space of 94 millims., has the sockets of an outer series of 12 teeth; and the fragment of the right ramus, I. 3, contains sockets of six outer teeth in the space of 51 millims. The greatest breadth of the largest lower-tooth crown is 12·5 millims., that of other crowns varying between 10 and 11·5 millims.

The head of this Cumnor Iguanodon, so far as may be inferred from the pieces recovered, may have been about 20 cm. long, a size which may be considered moderate. In its general form it was obviously much more lizard-like than crocodilian. The preponderance of Lacertilian resemblance is not merely a superficial one; it is evident in many structural details. In the occiput the shape, so far as is shown in this fossil (and in this it agrees with my Brooke Iguanodon-skull), has certainly a greater resemblance to that of a crocodile than lizard; but this superficial likeness is outweighed by the lizard-like entrance of the supraoccipital bone into the foramen magnum, from which it is excluded in the crocodile. In the upper surface of the skull the shape and size of the upper temporal openings, the form of the parietal bone, the division of the frontal bone, the large size and form of the nasal bones, are all lacertilian correspondences. The form of the maxilla, the mode of articulation of the mandible by a suspended quadrate not wedged into the side of the skull, and the dentition are other lizard-resemblances. On the under surface of the skull the downward extension of a median process of the basioccipital bone is at first sight a crocodilian feature; but it differs from the crocodilian's basioccipital in direction and relations. However, whatever value may be attached to this superficial similarity, it is more than balanced by the divided palate, shown by the free exposure of the basioccipital and basisphenoid bones throughout their whole extent, and by the absence from the maxillæ of any trace of palatal extension, or of attachment of those bones which in the crocodile close the palate and separate the nasal and buccal passages.

Vertebral Column.—Sixty-four centra and a considerable number of pieces of neural arch and processes give very complete information as to the structure of every part of the vertebral column. Of the centra 25 are præsacral, 4 are sacral, and 35 are postsacral or caudal. For convenience of reference, they have been consecutively numbered in what appears to be their natural sequence in the column; but probably several are missing from in front and behind the sacrum.

Neck (Pl. XIX. figs. 1–4).—Of the 25 præsacral vertebræ, 7 have, either wholly upon the centrum, or jointly on this and on the arch, an articular process for the attachment of the lower branch of a forked riblet—a lower or capitular costal facet, parapophysis—which stamps them cervical. Some are much crushed; and in all the neural arch is much mutilated. All are opisthocœlous, the posterior surface cupped, the anterior convex. Both surfaces retain marks of a concentrically laminated intervertebral cartilage. The contour of the anterior surface is almost a rhomb, in which the infero-lateral sides include an angle of about 100°; the upper angle is cut off by the neural canal; and the supero-lateral and infero-lateral sides include an angle of about 80°. The horizontal exceeds the vertical diameter. The lateral non-articular surfaces of the centrum are concave longitudinally, and they are indented by a depression, which is deeper towards the front. Below this depression the opposite sides of the centrum meet in a median keel. The borders, where at each end the sides and articular surfaces meet, and the keel are rugose in all the cervical vertebræ, as in most of the succeeding præsacral centra.

The atlas and axis are lost. In No. 1 of the cervical series the lower transverse process or parapophysis, preserved only on the left side, is an oval facet 5×4 millims. in extent, which projects from the side of the centrum, near its anterior border, below the semi-diameter. Close behind it, agglutinated to the centrum by matrix, is a small hatchet-shaped bone, having on one margin an articular facet, the form and size of which so nearly agree with those of the parapophysis as to suggest, in connexion with its nearness to this, that it is a neck-riblet. The sides of this centrum are convex in the vertical direction. From the size and position of the parapophysis, I think it probable that this vertebra was next to the axis, or the third in natural sequence.

In No. 2 the parapophysis is higher on the side of the centrum; it is also more prominent than in No. 1. It is close to the anterior border of the centrum, just external to the neuro-central suture. From it there passes backwards a ridge which divides the side of the centrum into a smaller upper area lying between the ridge and neuro-central suture and a larger lower area between the ridge and inferior median keel. The depression (mentioned in the description of No. 1) is in the lower area; and its deepest part is in front. A large vascular foramen pierces the bottom of the depression. The middle of the centrum is constricted, the horizontal transverse diameter being here 29 millims., whilst at the ends it is 40 millims. The upper surface of the centrum contributes at each end a large triangular piece to the floor of the neural canal; but at the middle of the canal only a narrow piece of it appears between the neurapophyses.

In No. 3 the parapophysis touches the neuro-central suture, which in front spreads outwards on its upper surface. The neurapophysis in this, as in all the neck-vertebræ, has an extensive attachment to the centrum, its antero-posterior dimension nearly equalling that of the upper surface of the centrum. At each end it spreads out very conspicuously. The arch, of which more is preserved than in any other neck-vertebra, was evidently dwarfed. On its left side, just external to the præzygapophysis, are indications of an upper transverse process for attachment of rib-tubercle, now broken off, a diapophysis, in the level of the spring of the arch.

In No. 4 the parapophysial facet rests jointly on the centrum and neurapophysis; but the former constitutes the greater part.

In No. 5 the parapophysis is similarly situated; but in No. 6 it is on a slightly higher level, the centrum contributing the lesser part.

In No. 7 the parapophysial facet lies just above the neuro-central suture, on the dilated antero-external corner of the neurapophysis.

In No. 8 no distinct trace of rib-facet is perceptible here; and in No, 9 the facet has certainly risen above the base of the neurapophysis.

Accounting all cervical in which the supporting process for the attachment of the rib-head is wholly or partly on the centrum, the neck of this Iguanodon certainly contained not less than 9 vertebræ. From the foremost of these preserved, No. 1 (probably the third in natural sequence) to the 7th, and indeed through the 8th and 9th, which in general form most resemble cervical centra, a gradual increase in bulk of the vertebral column takes place from the head to the trunk, and a gradual ascent of the parapophysis is observable.

The following measurements show the dimensions of Nos. 2 and 3, the least distorted centra in this series:—

	No. 2.	No. 3.
	mm.	mm.
Length along upper surface of centrum	41·	40·5
,, ,, lower ,, ,, ...	35·5	41·
Diameters.		
Anterior surface, vertical	25	26
,, ,, horizontal	37	42
Posterior surface, vertical	30	31
,, ,, horizontal	40	41
Horizontal diameter at middle of centrum......	29	36

The typical cervical vertebræ are followed by a few in which the anterior articular surface becomes plane, and the posterior is less hollow. In these there is no rib-head facet upon the centrum; but in one (Pl. XIX. fig. 5), No. 11, which retains a large part of its neural arch, this facet is on the anterior margin of the (upper) transverse process, very close to the præzygapophysis. It is an oval, 17 × 19 millims., directed outwards, and indicates a rib of considerable stoutness. The transverse process—diapophysis—is broken off just beyond the rib-facet. It had a broad basal attachment to the arch in the level of its crown, extending from the præ- to the postzygapophysis, after the manner of the platform mentioned by Prof. Owen as characteristic of *Iguanodon Mantelli*. This platform is upborne by a strong buttress, which rises obliquely forwards to its under surface from the lower and back part of the neurapophysis near the neuro-central suture. In front of this buttress is the parapophysial facet, and behind it is a deep three-sided hollow. The præzygapophyses of this vertebra look upwards and inwards. A line drawn perpendicularly to the plane of the left præzygapophysis includes, with the spinous process, an angle of about 45°. The sides of this centrum (No. 11) are concave longitudinally and gently convex vertically. The keel is less strongly marked than in the cervical vertebræ. The length of the neural surface of this centrum is 50·5 millims., and the vertical diameter of the articular ends is 38 millims. The length of No. 10 is 42 millims.

In No. 13 the rib-head facet lies further outwards from the præzygapophysis upon the transverse process than in No. 11. This vertebra is therefore thought to have occupied a place in the vertebral column posterior to No. 11. The length of the centrum, measured along the neural surface, is 55 millims.; and the vertical diameter of the articular end is 46 millims. The sides are much crushed; but it is evident, notwithstanding this mutilation, that the horizontal diameter of the ends did not exceed the vertical as in the neck. The borders of the articular ends are prominent and slightly everted.

The anterior articular surface of all the præsacral vertebræ behind where the neck and trunk join (in which region it is plane) is slightly hollow; and this is also its shape in the tail. The posterior articular surface of all the vertebræ behind the neck is decidedly concave. This character—the greater concavity of the posterior articular surface—is of use in determining the direction of a dissociated centrum when other indications are lost.

The sides of the centrum, in what I may call the middle dorsal region, are gently convex in the vertical direction, and concave longitudinally. At its middle the centrum is slightly constricted. The constriction is much less than that represented in the figure of a thoracic vertebra of *Iguanodon Mantelli* given by Prof. Owen in the Foss. Rept. of the Wealden Formation, Suppl. II. t. 7. fig. 6.

In No. 11 the facet for the rib-head is 9·5 millims. distant from the præzygapophysis; in No. 13 it is 18·5 millims. from it; in No. 18 the interval is nearly the same. It appears from this that the outward movement of the capitular facet, from the root of the (upper) transverse process—diapophysis—to the free end of this, takes place through a larger series of vertebræ in this Iguanodon than in extant crocodiles, and that the middle thoracic region was longer in the Dinosaur. In a skeleton of *Crocodilus niloticus*, presented in 1875 to the Hunterian Museum by the Hon. E. F. C. Berkeley, at the 19th vertebra the capitular costal facet merges into the tubercular facet at the free end of the transverse process; and the rib articulating here retains scarcely any trace of division. In this skeleton the passage of the capitular facet from the centrum to the free end of the diapophysis is completed through a chain of 8 vertebræ, the 12th to 19th inclusive. In this Iguanodon's vertebral column the capitular facet, withdrawn from the centrum in No. 8, is still near the root of the diapophysis in No. 18. The large proportion of Iguanodont vertebræ in which the rib-head facet is close to the præzygapophysis, which I have obtained in the Isle-of-Wight Wealden beds, had long attracted my notice.

Behind No. 16 the bulk of the centrum much increases. Many of the centra in the front and middle of the trunk are much crushed; but, allowance being made for this mutilation, the excess of the horizontal over the vertical diameter, so noticeable in the articular ends of the centra in the neck, is clearly not repeated here.

In No. 17, where the centrum has escaped distortion, the anterior articular surface has a nearly circular outline; its horizontal and vertical diameters are each 51 millims. The vertical diameter of the posterior end is also 51 millims., the horizontal being somewhat greater, 57·5 millims. The borders of both ends are prominent, and slightly everted (as in the root of neck); and the rugosity of the adjoining part of the lateral non-articular surface is strongly marked. The sides of the centrum here, as in the anterior thoracic region, are gently convex vertically. The inferior median keel is less prominent here than in the last-mentioned region. The constriction of the middle of the centrum is also in these Cumnor fossils less than in those from the Wealden formation, described in the work to which reference was very lately made. The transverse horizontal diameter of No. 17 at its middle is 41 millims, at the anterior end 51 millims, and at the posterior end 57 millims. In this part of the column the præzygapophysis has a more horizontal direction than in the front of the trunk.

In the loins the centrum increases greatly in bulk, and this more by augmentation of its width and depth than by addition to its length. In No. 21, which I place here, the horizontal diameter of the anterior articular surface is 64 millims., and the vertical diameter 56 millims.; the same diameters of the posterior articular surface are 74 and 52 millims., the horizontal diameter in both instances preponderating. The average length of the centrum in this region is 54 millims. These proportions give to the lumbar centra an appearance of stoutness and shortness. The anterior articular surface is very flat, whilst the posterior surface is distinctly concave, the concavity being greater in the vertical than in the horizontal direction. The sides of the centrum are, in the vertical direction, more cylindroid than in the dorsal region. The inferior keel is more marked than in the posterior dorsal vertebræ, owing to a slight flattening of the surface on each side of it, which increases its prominence. The anterior articular processes look inwards and upwards. The posterior articular processes greatly overhang the plane of the posterior surface of the centrum. They are separated from one another by a deep groove. The neuro-central suture is almost the same length as the upper surface of the centrum; but the neurapophyses soon contract, principally by the forward slant of their posterior border. In No. 20 the lengths of the neuro-central suture and centrum are 50 millims., whilst at the height of 15 millims. the neurapophysis has an antero-posterior extent of only 32 millims. (Pl. XIX. figs. 6–8.)

The spinous processes of all the præsacral vertebræ have been broken off. So far as may be gleaned from the stumps remaining on some of the arches and from detached dissociated fragments, they had in the trunk a great antero-posterior extent; near their root their front margin is a thin edge; their posterior border is deeply grooved; they had a backward slant. In none of the trunk-vertebræ is there any indication of a capitular costal facet on the pier of the arch, as represented in the figure of the dorsal vertebra of *Iguanodon Mantelli* in the Fossil Rept. of the Cret. and Weald. Formations, p. 109, pl. 35; and the evidence afforded by these remains (it is not claimed to be complete) seems to show that the rib-head facet, when it left the neuro-central suture, passed directly from this to the (upper) transverse process, as in extant crocodiles. In the skeleton of *Croc. niloticus* the transfer occurs at the 12th vertebra, in which the capitular facet is on the diapophysis, whilst in the 11th vertebra it is on the neuro-central suture.

Sacrum (Pl. XX. figs. 1, 2).—The true sacral vertebræ (as defined by their ankylosis, the junction of the free ends of their lower transverse processes, and the connexion of these with the ilium) are four. Although now disconnected (ankylosis not having yet occurred, owing to the immaturity of the individual), the terminal surfaces of the centra fit each other so truly that their natural sequence is not, I think, open to doubt.

With the anterior surface of the foremost sacral centrum articulates another, in precisely the same manner as that in which the true sacral centra are joined together. It is the last lumbar vertebra, No. 23. By the identity of its mode of union to the first sacral centrum, and by the large support it affords to the first-sacral lower transverse process, it so closely resembles the true sacral vertebræ, and dynamically forms so obviously a part of the sacrum, that Drs. Melville and Mantell were not very culpable in regarding it as the first true sacral centrum.

The last lumbar (Pl. XX. figs. 1, 2, *ll*) is bulkier than any of the true sacral centra. Its form is depressed; its anterior articular surface is nearly plane, very slightly concave. It is smooth; and it was evidently capable of movement upon the next centrum in advance, to which it was attached by an intervertebral disk of the ordinary structure and form, the marks of which are still apparent. The vertical diameter of this face is 52·5 millims., and the horizontal diameter about 66 millims. Its posterior terminal surface is plane. It is marked by radiating impressions suggestive of intimate union to the next centrum by a thin film of ossifying cartilage. Its minimum horizontal diameter in the plane of the neural canal is 40 millims., and its maximum diameter, which is nearly on the level of its mid-height, is 71 millims. It will be seen from a comparison of these numbers how greatly the centrum expands behind. Here near the posterior border the centrum attains the maximum horizontal diameter of 91 millims., forming the anterior boundary of a deep notch in the articulated sacrum between the last lumbar and first sacral centrum, which afforded a very firm attachment to the first lower sacral transverse process. The sides of the last lumbar centrum, in the vertical direction, at first slope outwards from the neural surface until the level of the lower limit of the notch just described is reached. From here they bend rather abruptly inwards to an inferior median keel, at each side of which the surface is transversely nearly plane. Longitudinally the sides of the centrum are very concave; the concavity is increased by the prominence of the posterior margin. The neuro-central suture is relatively shorter than in the other lumbar vertebræ; the groove of exit for the last lumbar nerve limits it behind. At a short distance from its posterior limit the suture has a conspicuous indentation, repeated in the last true sacral vertebra.

The first true sacral centrum (No. 24) is much smaller than the last lumbar. In front, at its junction with this, it is much expanded, but towards its middle it rapidly contracts. The inferior median keel, conspicuous in the last lumbar centrum, is here scarcely noticeable. The form of the centrum is more cylindroid;

its neural arch plainly rested chiefly on this, its proper centrum, and was only to a very limited extent borne on the last lumbar. The length of the neuro-central suture is only about $\frac{2}{3}$ of that of the upper surface of the contrum, the attachment being limited behind by the wide groove of exit of the first sacral nerve, which emerges over the side of the centrum rather behind its middle. Behind this nerve-groove is the rough sutural surface descending on the postero-lateral border of the centrum, of which the upper part afforded a limited attachment to the neural arch of the second sacral vertebra, and the lower part formed one side of the notch between it and this latter, where the second lower sacral transverse process was implanted. This process was evidently smaller than the first.

In the second sacral centrum (No. 25), the dimensions of the anterior and posterior terminal surfaces do not much differ. The centrum is evenly and slightly constricted at its middle. The non-articular part or side is cylindroid in the vertical direction, slightly flattened below the neuro-central suture, and again at its under surface, where longitudinally it is concave. It has no median keel. The groove of exit for the 2nd sacral nerve is slightly further back than the corresponding groove in the 1st centrum. The notch in the posterior border of the centrum for the second lower transverse process descends only a slight distance.

The third sacral centrum (No. 26) differs little from the second. Its under surface is somewhat flatter, and towards the posterior border it has a slight depression. Its lower transverse process is partly borne on the postero-lateral border of the second centrum. The groove of exit for the third sacral nerve is slightly nearer the posterior border of the centrum.

The fourth sacral centrum (No. 27) is distinguished from the others by the smoothness and concavity of its posterior surface, which evidently allowed the anterior caudal centrum to play upon it through the medium of an ordinary intervertebral disk. The neural arch rests on the whole length of its own centrum and slightly on the third centrum. The fourth sacral nerve emerged through the intervertebral foramen between it and the first caudal vertebra, and not across the side of its own centrum as in the first three sacral vertebræ. The under surface shows the same flattening and slight hollow noticed in the third centrum.

With the exception of the anterior surface of the last lumbar or false sacral vertebra, and of the posterior surface of the fourth sacral centrum, all the terminal surfaces of the sacral vertebræ are rough; their union with one another was evidently too intimate to allow of movement; and had the animal reached maturity they would probably have become coossified.

The length of the entire sacrum, including the last lumbar vertebra, is 29 centims., that of the last lumbar being 52 millims.; of the 1st sacral centrum, 50 millims; of the 2nd, 53 millims.; of the 3rd, 49 millims.; of the 4th, 50 millims. When the centra are articulated the outline of the under surface of the sacrum is rendered sinuous by the constriction of the middle of the centra and the prominence of their terminal borders.

The neural canal correspondiug to the last lumbar and three foremost sacral centra is very capacious; at the fourth centrum it becomes abruptly contracted.

It will have been noticed that only the false sacral centrum (last lumbar) wholly supports it own neural arch, and that, as regards the four true sacral centra, the arch, whilst resting mainly on its own centrum, is also borne in part on the centrum next before it. This seeming advance of the arch, by which it comes to lie over the interval between two centra (first noticed, I believe, by Owen in a Wealden sacrum referred by him to *Iguanodon Mantelli*, formerly in the collection of the late Dr. Saull, and at his death acquired by the British Museum, and also found by him in a sacrum of *Megalosauras*), has its probable explanation in the persistence throughout life of an early embryonic phase. In the chick it has been ascertained that each permanent vertebra comprises the anterior and posterior halves of two consecutive protovertebræ. The neural arch, after this second segmentation of the vertebral column, comes to rest on the anterior half of the permanent vertebra. The intervertebral space between two permanent vertebræ corresponds to the middle of the centrum of a protovertebra.

In the Dinosaurian sacrum it appears as if the transformation of the proto- into the permanent vertebræ was not completed in the sacral region of the column; the second segmentation mapping out the permanent centra is effected, but the arches retain their primitive positions.

On comparing this Cumnor sacrum with the type fossil in the British Museum, to which I have very recently referred (No. 37685, Brit.-Mus. Catal.), some notable differences are evident. Of these, the smaller number of centra, 4 in the Cumnor sacrum (the British-Museum sacrum has 5 centra), is the most important. It is certain that 5 is the true number of centra in the latter; for they are firmly coossified in undisturbed natural sequence; but the reference of this fossil to *Iguanodon Mantelli* wants the confirmation which its association with other indubitable Iguanodon-remains might have afforded, and no such verified sacrum has since been found with which to compare it.

The proportions of the centra in the Cumnor and British-Museum sacrum No. 37683 are also very different, as the subjoined measurements show. In the former the centra are shorter and stouter, and they want the remarkable lateral compression and strongly carinate form so conspicuous in the latter, which is well represented in Prof. Owen's figure of this in his Foss. Rept. Wealden Formation, t. iii.

Measurements.

	Last Lumbar.	1st Sacral.	2nd Sacral.	3rd Sacral.	4th Sacral.	5th Sacral.
Wealden Sacrum. (No. 37685, Brit.-Mus. Cat.)						
Length along under-surface...............	mm. 71	mm. 62	mm. 80	mm. 65	mm. 76·5	mm. 76
Transverse horizontal diameter at middle of centrum	...	35	28	28	28*	65
Cumnor Iguanodon.	(No. 23)	(No. 24)	(No. 25)	(No. 26)	(No. 27)	
Length of centrum...	52	56*	52*	52*	52*	
Horizontal transverse diameter at middle of centrum	69·5	44	41·5	43	43	

That these differences of form have a specific value will be, I think, allowed by all. The fewer sacral vertebræ in the Cumnor sacrum have a somewhat higher import. Have we here an earlier phase in the development of the Dinosaurian sacrum than that exemplified in *I. Mantelli*? The earlier age of the Cumnor Iguanodon, as indicated by its gisement, Kimmeridge Clay, would be in harmony with this.

Tail.—Thirty-five postsacral vertebræ are recovered. It is probable that a couple of the foremost are missing, since all those procured have chevron-facets, and in extant lizards and crocodiles these are absent from a small number of the foremost caudal vertebræ.

In No. 28, probably the foremost of our series, the centrum is larger than in those which I have placed behind it. The anterior articular surface is nearly plane, very slightly concave, whilst the posterior surface, as in all the other caudal vertebræ, is distinctly concave. The sides of the centrum are, in the vertical direction, gently convex; they meet at the under surface of the centrum in a blunt wedge-form. In the longitudinal direction they are gently concave. The under surface at each end is encroached on by the chevron-facet, which is continuous with the terminal articular surface. In this vertebra (No. 28) the length of the neural surface is 50·5 millims., and the distance between the anterior and posterior chevron-facet on the under surface is 19 millims. A strong transverse process juts out from the neurapophysis at the height of 12 millims. above the neuro-central suture.

No. 29 (Pl. XIX. fig. 9) has a peculiar and distinctive obliquity, produced by the downward and backward slant of its under surface,

* Approximate measurements; small chips off edge prevent actual measurements of this dimension.

which meets the chevron-facet at an acute angle. (I have obtained similar caudal vertebræ in the Isle of Wight.) The sides of the centrum are vertically slightly convex. The narrow under surface is more encroached on by the anterior than by the posterior chevron-articulation. The transverse process arises rather lower than in No. 28. The spinous process has a strong backward slant.

Through the next four vertebræ, Nos. 30–33, the transverse process sinks on the arch towards the neuro-central suture, and it also becomes smaller. In No. 30 its size is greatly reduced, and it arises in the plane of the neuro-central suture, which is very indistinct. In No. 35 a slight swelling is the only vestige of the transverse process; and even this is absent from the succeeding vertebræ.

The suppression of the transverse process is soon followed by the disappearance of the neuro-central suture, which ceases to be recognizable in No. 37. Of the succeeding centra many have been much squeezed in by laterally applied pressure. To this they have yielded in such a manner as to suggest that the middle of the centrum was very imperfectly ossified, and perhaps permanently cartilaginous, as was thought characteristic of the caudal vertebræ referred to *Poikilopleuron*, but is now known to obtain in *Megalosaurus*. In No. 37, the 10th in the caudal series, the posterior chevron-facet is notched in front; and from this notch a slight groove passes forwards along the under surface of the centrum.

In No. 41 (Pl. XIX. fig. 11) the anterior chevron-facet has almost disappeared. On the side of the centrum is an angular longitudinal ridge; between this and the situation of the neuro-central suture is a shallow depression; and below the ridge a small better-marked hollow. The ridge is gradually lost in the succeeding centra. The reduction in bulk is attended with diminution of length of the centrum.

In the smallest vertebræ, towards the end of the tail, the centrum has a simple cylindroid form (Pl. XIX. figs. 12, 13). In these the arch is reduced to extreme simplicity, a mere hoop bearing an anterior and posterior pair of articular processes. The spinous process ceases in No. 51. A slight rugosity marks the situation of the chevron-joint, so conspicuous in the first half of the tail. The anterior chevron-facet first disappears. Both articular surfaces in all the caudal vertebræ are concave.

The change in form of the articular surfaces of the vertebral centra, traceable through the column, is highly instructive. In the neck these surfaces are convexo-concave, opisthocœlous; at the root of the neck the anterior ball is less convex, the posterior cup less deep; in the fore-trunk the anterior surface is plane, the posterior slightly concave; in the loins the anterior surface is very slightly concave, the posterior surface more so; and in the tail both surfaces are concave. Variation in length of centrum, shown by the annexed measurements, is not less worthy of notice; for it had been asserted that the length of centrum was constant for the same vertebral column, although this is not borne out by the skeletons of extant reptiles.

Lengths of Vertebral Centra measured along tehir upper surface.*

Neck.		Trunk.		Tail.	
	mm.		mm.		mm.
No. 1 ...	43·	No. 10...	42	No. 28 *a*.	50·5
„ 2 ...	41·5	„ 13...	56	„ 28...	50·
„ 3 ...	41·5	„ 15...	56	„ 37...	53·
„ 6 ...	37·	„ 18...	58	„ 47...	47·
				„ 51...	39·5
				„ 55...	32·
				„ 57...	26·
				„ 58...	24·

Pelvis and Hind Limbs.—The sacrum has just been described; the other parts referable to the hip-girdle are portions of both ilia, of both pubes, and of one ischium. The limbs are represented by pieces of both femora, of both tibiæ and fibulæ, ossa tarsalia, metatarsals, and phalanges.

Ilia, No. iv. 1.—Part of the right ilium comprises the acetabulum and all that part of the broad flat plate which lies above and behind it. The greatest vertical dimension at the acetabulum is 135 millims.; the length of the mutilated præacetabular part is 110 millims.; the coxal articular surface is an oblong, 80 millims. long. It is widest behind, being here 43 millims. across. This surface, which is coarsely pitted (as if an epiphysial incrustation had been detached from it) is imperfectly divided at 45 millims. from its posterior limit by a slight projection. The part behind this is hollowed; that in front of it is nearly plane, or slightly convex. From the hinder and outer corner of the joint-surface a prominent angular ridge curves upwards and forwards over the joint, and gradually subsides on the smooth surface above it. A conspicuous sinuous line above the acetabulum probably marks the attachment of the capsular ligament. That part of the ilium which comprises the joint is the stoutest part of the bone. The inner surface of the ilium is sinuous. Above the acetabulum are the impressions of attachment of sacral ribs.

The pieces iv. 2, *a*, *b*, *c*, *d*, are fragments of the left ilium. Of these, iv. 2 *a* shows that the acetabular part was produced forwards as a long slender process, which was longer than the postacetabular part of the bone.

Pubes.—The fossils iv. 16, iv. 17, correspond essentially with Wealden Iguanodont bones, now, I think, generally accepted as pubes. They are too mutilated for description. They show that the pubis formed part of the acetabulum as in Lizards.

Ischium.—The peculiar curve of the fossil iv. 18, and the process indicated on one margin near the stouter end, identify this as part of the long blade of an Iguanodont ischium.

Femur.—These large and strong bones are principally represented by their extremities. The head, iv. 3, iv. 4, has the subglobular

* The lengths of the sacral centra are already given in another Table.

form met with in Wealden thigh-bones. The condyles have been much split (iv. 12, 13, 10, 11) into many pieces; but the deep narrow anterior intercondyloid notch, characteristic of the femur of Wealden Iguanodonts, is plainly recognizable here. The medullary cavity was very large; and the portions of bone referable to the diaphysis show that this was a relatively thin tube of bone enclosing a very large quantity of unossified substance.

Tibiæ.—The pieces iv. 5, iv. 6, are the knee ends of the right and left tibiæ. They show an imperfect condylar division of the gonal surface, and that the præcnemial crest was remarkably large and strong. The fossil iv. 7, the distal end of the left tibia, agrees essentially in form with the same part in Wealden Iguanodons from the Isle of Wight. The entering angle in the antero-external surface, the salient angle in the postero-internal surface, and the malleolar division of the articular surface into a stouter and shorter inner and a narrower and longer outer half, each having a different aspect adapted to corresponding subdivisions of the proximal surface of the tarsus, are well illustrated by these fossils.

Tarsus.—This comprises two distinct bones, a larger inner bone, the equivalent of the astragalus (Pl. XX. figs. 5, 6), and a smaller and outer one, the representative of the calcaneum (Pl. XX. figs. 3–6).

The astragalus agrees substantially with the Wealden form *. It has a somewhat quadrilateral figure. The upper surface is the counterpart of the inner two thirds of the distal articular surface of the tibia as far outwards as the notch in this latter, but not including what may be conveniently called the outer tibial malleolus. It is divided into two parts, each of a rudely triangular outline. Of these the inner and larger, a wide shallow hollow, looks upwards, inwards, and backwards, whilst the outer division, a deep narrow trough, looks upwards, outwards, and backwards, when the bone is placed in the position it would take if it were articulated with the tibia, and the longer axis of the distal end of this latter were directed from without and behind forwards and inwards, the direction it probably had in progression.

The under surface of the astragalus forms the larger inner part of a wide articular pulley, convex from behind forwards, and gently concave from without inwards. This trochlear surface rises some distance on the front of the bone. The inner border of the bone is so deep that it deserves to be termed a surface. It is smooth; its outline is a rude crescent with blunted horns. Of these the posterior meets the hinder border of the bone (a thin lip with a downward and forward slant) in an angle which underlies the salient posterior angle of the tibia. The anterior surface forms the ascending lip or process, which fits into the retiring angle in the front of the tibia. The inner half of this lip rises gradually; and the outer falls abruptly. The outer border of the bone, much shorter and much thinner than the inner, is the outer boundary of the narrow trough-like part. Here the upper or tibial and the trochlear surface nearly meet.

* See Quart. Journ. Geol. Soc. vol. xxx. p. 24.

The Calcaneum (Pl. XX. figs. 3, 4), smaller than the astragalus, is (to borrow a simile from the older anatomists) a somewhat boat-shaped bone, wider behind than in front. It has an upper, an under, and an outer surface. The under surface is crescentic, strongly convex from back to front, and less convex transversely. It forms an arc of a circle, and was plainly part of a trochlear joint. The upper surface is subdivided by a prominent ridge, directed obliquely from behind forwards and inwards, into a posterior part, a deep trough parallel with the ridge, and an anterior part somewhat quadrilateral in shape, with the anterior corners rounded off, and the outer and posterior sides longer than the two others. The outer surface, vertical, is non-articular; below, behind, and in front it is slightly encroached on by the trochlear surface. Its lower border is an arc; its upper border is straight. Rather behind the middle this latter is interrupted by the outer end of the ridge mentioned as subdividing the upper surface. The inner border of the bone is thin and crenated; here, as lately mentioned, the upper and under surfaces nearly meet.

When the calcaneum is placed with the border which I have termed inner touching the outer border of the astragalus, and the upper or crural surfaces of the bones are viewed, it is evident that the deep trough in the calcaneum behind the oblique ridge in its upper surface forms the outward continuation of the trough in the outer half of the upper surface of the astragalus, and that it articulates with the outer tibial malleolus, which, as I have already said, is not borne on the astragalus. The quadrilateral depression in the upper surface of the calcaneum, lying in front of this tibial trough and of the oblique ridge, received the lower end of the fibula, the distal part of the shaft of which rests in a splint-like manner on the front of the tibia parallel with its outer border. Viewed from beneath, the convex under surface of the calcaneum is seen to complete the pulley, of which the astragalus forms much the larger part. The mutual adaptation of the two bones is so suggestive, that this alone would have justified the identification of the lesser bone with the os calcis, a bone previously unrecognized; but I fortunately obtained confirmation of the true skeletal position in a hind foot of *Hypsilophodon Foxii*, a closely allied form, in which I found the bones *in situ* joined to each other, as also to the tibia and fibula, in the manner described *.

In the articulation of its tibia with the calcaneum, as well as with the astragalus, the Iguanodon's foot differs from the hind foot in the three extant orders, Chelonia, Lacertilia, Crocodilia—in each of which the distal end of the tibia rests wholly on the astragalus, which latter, by an outer facet, is in contact with the fibula. But in the very point wherein the Dinosaurian foot differs from that of living reptiles, it closely resembles the foot of birds.

* Since this was written, by the courtesy of M. E. Dupont, the Director, I have had an opportunity of studying some of the very instructive Iguanodon-remains lately acquired by the Museum of Natural History at Brussels, and have been gratified by finding the bones in natural articulation as described.

In a communication to the Geological Society, in 1869, Prof. Huxley demonstrated the agreement of the Dinosaurian astragalus, which he had shortly before identified in *Megalosaurus*, with the distal condylar element of the bird's tibia, which Gegenbaur had shown to comprise the equivalent of the astragalus in extant reptiles.

In most birds, as is well known, the individual distinctness of the tibio-tarsal elements is soon lost by the accrescence of the tarsal part to the tibia, their individuality continuing longest in the keelless birds, of which the *Apteryx* furnishes an admirable example. In Dinosauria, Prof. Huxley showed that the astragalus remained a distinct part throughout the whole life. In the bird, as remarked by Gegenbaur, the combination of two tarsal elements in the single bone which is regarded as the equivalent of the astragalus, is hinted by the facility with which, at an early embryonic stage, the bone sometimes separates into two pieces in the attempt to detach it from the tibia. In this Cumnor Iguanodon, and also in the Wealden Iguanodon and in *Hypsilophodon*, the distinctness of the calcaneum is clearly preserved throughout life. It obtains also in *Megalosaurus*, and it may fairly rank as a Dinosaurian character. In Dinosauria the astragalus and calcaneum together are the homologue of the astragalus of the young bird.

In the grown bird the relation of the fibula to the calcaneum is not apparent; but it is otherwise in early embryonic existence, when the fibula and tibia are of equal length, and the distal end of the former reaches the mass of tissue out of which the proximal tarsal element is afterwards evolved. In the Iguanodont foot these early developmental phases are, as it were, permanently fixed.

Amongst the Cumnor fossils there are none which I can identify as elements of a distal tarsal row; and from the study of two hind feet of Iguanodon which I dug out in the Isle of Wight, and also of several feet of the allied *Hypsilophodon*, I suspect that such elements, if they ever had a distinct existence, soon lost it by fusion with the basal ends of the metatarsals. This coalescence of distal tarsal elements with the metatarsus is foreshadowed in *Compsognathus*, in which the former are represented by thin inconspicuous disks united to the metatarsals, a narrow line marking their primitive separateness. In *Iguanodon* probably such separateness is restricted to the embryo.

Metatarsus.—Parts of four bones are referable to this segment of the foot. Nos. iv. 24, 25, 26, are the distal trochlear ends probably of the two lateral and the middle metatarsals of the right foot; iv. 27 is the trochlea of the left middle metatarsal. Nos. 33, 35, 36, are fragments of their proximal ends and shafts.

The trochlea is wide and shallow. In the middle metatarsal it reaches higher on the front of the joint than in the lateral metatarsals, and the outer is rather stouter than the inner condyle. In the lateral metatarsals the condylar division, less marked in the outer one, is restricted to the plantar surface, and the front of the joint is convex transversely and in the direction of the long axis of the bone. In the inner metatarsal the inner condyle is narrow and prominent, the outer condyle broad and low.

Phalanges.—Of these 13 are preserved; iv. 29, 22, 39, are probably the 1st, 2nd, 3rd phalanges of the inner toe of the right foot; their greater length distinguishes them from iv. 42, 43, which are referable to an outer toe, the phalanges of which are distinguished for their shortness. The unguals are very strong, laterally compressed, and impressed with a deep submarginal nail-groove.

Shoulder-girdle and Fore Limb.—The only parts of the segment of the skeleton which can be certainly identified are the scapulæ and proximal ends of the humeri.

The Scapulæ, iii. 1, 2*a*, 2*b*, closely resemble those of Wealden Iguanodons from the Isle of Wight. The glenoid end shows the usual rough sutural coracoid surface, and the smooth concave glenoid part for articulation of the humerus. The coracoid part near its posterior border is furrowed by a conspicuous groove, which enters it from the thoracic aspect. The dorsal end of each scapula is missing, so that the length of this bone is unknown.

The fossil iii. 6 so closely resembles typical Iguanodont coracoids, that its nature can scarcely be doubted. Its form is simple, as in Wealden Iguanodonts; and, as in these, it is remarkable for its relatively small size.

No. iii. 4 is, I have no doubt, the proximal end of the left humerus. In its general form, and especially by the presence of a strong process at its posterior border, it closely imitates a very large humerus which I obtained several years since at Brooke Bay. No part of the shafts or distal ends of the humeri can be identified; nor can I speak with certainty of the bones of the forearm. Some imperfect bones, which I regard as metacarpals, are more slender, and appear to have been relatively longer than the metatarsals. A reconstruction of the fore foot out of these imperfect and dissociated remains must necessarily be so conjectural that I have not attempted it.

For this Kimmeridgian Iguanodon, the distinctness of which from the Wealden *I. Mantelli* is demonstrated (*a*) by the different shape of the thoracic vertebræ, the centrum of which is wedge-shaped in the Kimmeridgian Iguanodon, very constricted in the Wealden Iguanodon, (*b*) by the flattening of the under surface of the centra in the sacrum of the Kimmeridgian, which in the Wealden is keeled, (*c*) by the smaller number of sacral centra in the Kimmeridgian Iguanodon, and (*d*) by the relative simplicity of the marginal serrature of its teeth, I propose the specific name *Prestwichii*—*Iguanodon Prestwichii.*

EXPLANATION OF PLATES XVIII., XIX., XX.

All the figures are two thirds of the actual size, except those of the jaws, which are ×2, and figs. 8, 9, Pl. XX. which are diagrammatic.

Plate XVIII.

Fig. 1 (No. I. 10). View of undersurface of part of vault of skull. *f*, frontal bone; *pf*, postfrontal; *p*, parietal.
2. The upper surface of the same fragment. The lettering is the same.
3. Fragment of occiput. *fm*, foramen magnum; *so*, supraoccipital.
4. The under surface of a fragment of the base of the skull. *oc*, occipital condyle; *Bo*, basioccipital; *Bs*, basisphenoid; *c*, carotid groove; *hp*, hypophysial pit.
5. The upper surface of the same piece.
6. Fragment of the right maxilla (outer surface) showing three teeth:—1, a mature germ, not yet in wear; 2, a crown, which was in full use at the death of the animal; the free edge is not in the line of actual wear, but an accidental fracture; 3, a fang extended considerably beyond the border of its socket.
7. Another fragment of a maxilla, showing:—*s*, an empty socket; *f*, the fang of a tcoth, of which the crown had been fully extended, and in full wear. It tapers to a blunt point; and the pulp-cavity, large at the junction of the fang and crown, is contracted to a small opening at the free end of the fang. *g*, a mature germ, at the base of which are remains of an almost completely extended fang.
8. A fragment of the dentary part of mandible. 1, 3, 5, fangs, of which the crowns must have been almost worn away; 2, 4, 6, crowns of teeth in full wear; 7, 9, 11, germs, of which about half is extruded beyond the inner parapet of the aveolus; 8, 10, smaller germs, of which only the tip is visible.

Figs. 6, 7, 8, are ×2.

Plate XIX.

d, diapophysis; *p*, parapophysis; *prz*, præzygapophysis; *psz*, postzygapophysis; *a*, anterior articular surface.

Fig. 1. Front view of cervical vertebra (ii. 3).
2. Posterior view of the same.
3. Side view of the same.
4. Inferior view of the same.
5. Side view of a thoracic vertebra (ii. 11).
6. Side view of a lumbar vertebra (ii. 20).
7. Anterior view of the same.
8. Posterior view of the same.
9. Side view of a caudal vertebra, from near sacrum (ii. 28). Centrum oblique (ii. 28).
10. Side view of a caudal vertebra (ii. 32) posterior in position to ii. 28.
11. Side view of a caudal vertebra from a part of the tail where the transverse process has disappeared (ii. 41).

12 (ii. 53) & 13 (ii. 58). Vertebræ from very near the end of the tail.

Plate XX.

Fig. 1. The last lumbar vertebra and the sacrum, seen from below.
2. The same, seen from above.
In both, *l l*, last lumbar; 1*s* 2*s*, 1st & 2nd sacral centra; *ne*, neural canal; *ng*, nerve-groove.
3. The os calcis, its outer surface.

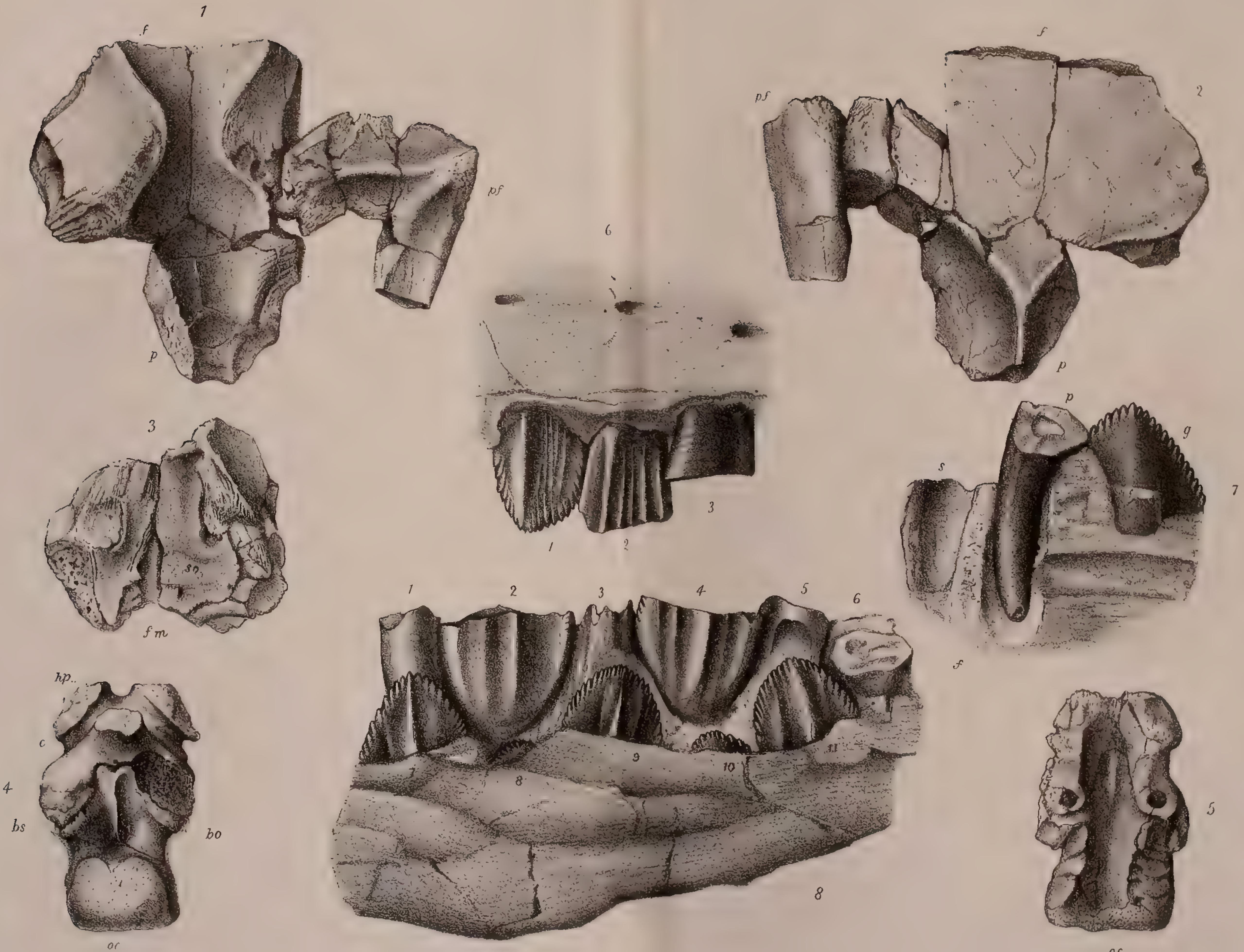
4. The same, its upper surface. *f*, the fibular portion; *t*, the tibial portion.
5. The astragalus (*a*) and os calcis (*c*), seen from below.
6. Front view of the bones of the legs, with the proximal tarsal series: *t*, tibia; *f*, fibula; *a*, astragalus; *c*, calcis.
7. Side view of same.
   This and the preceding figure are *restorations*.
8. The leg and proximal tarsal elements of a young fowl. The letters indicate the same parts as in fig. 6.
9. The hind limb of a chick, showing at this stage the fibula as long as the tibia, and the distinctness of the tarsal elements. After Gegenbaur.

Discussion.

Prof. Owen stated that a specimen existed in the British Museum showing the bones of the hinder limb of a Dinosaur, i. e. *Scelidosaurus*, which, though never referred to, gave much information as to the homologies of the bones. This paper, however, was most valuable, and he believed the author had established the specific distinctness of the form. He asked Prof. Seeley what genus in the Mammalia gave a dentition like that of the Triassic *Placodus*. He found it in *Ornithorhynchus*; but the broad, flat crushers were uncalcified in that sauroid Mammal.

Prof. Seeley spoke of the high value of Mr. Hulke's paper. Specimens existed in Belgium showing the bones of *Iguanodon* in situ, and gave independent evidence of the accuracy of the author's conclusions; but those who had seen them could not, as they had been shown in confidence, describe them. He thought the specimen on the table showed traces of Teleosaurian characters in the expanded frontal bone and in other parts of the skeleton. He would even attach more value than the author had done to the differences of the vertebral column, pelvis, teeth, and limb-bones from those of the ordinary *Iguanodon*; and he thought they might be generic, rather than dependent on age. He attached great importance also to the separation of the astragalus and the os calcis. Here there could be no doubt of specific distinctness from Wealden forms; and he believed that the differences were important enough to justify the author in placing the animal in a new genus.

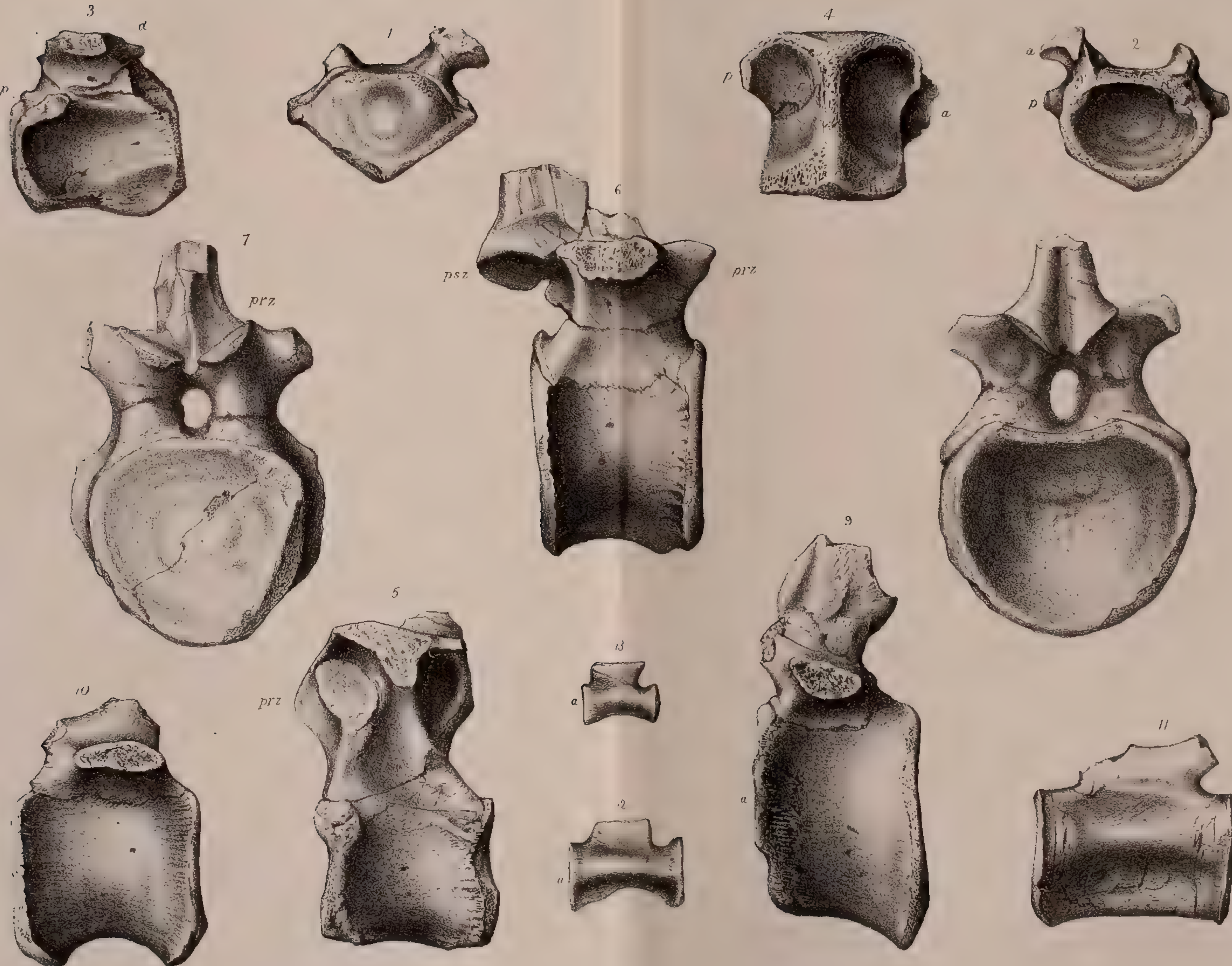
Mr. Hulke said he had studied the specimens of *Scelidosaurus* much, and doubted whether the bones were truly not displaced. The Belgian specimens, however, gave the fullest evidence of the structure of the Dinosaurian tarsus.



J Berjeau lith

Hanhart lith

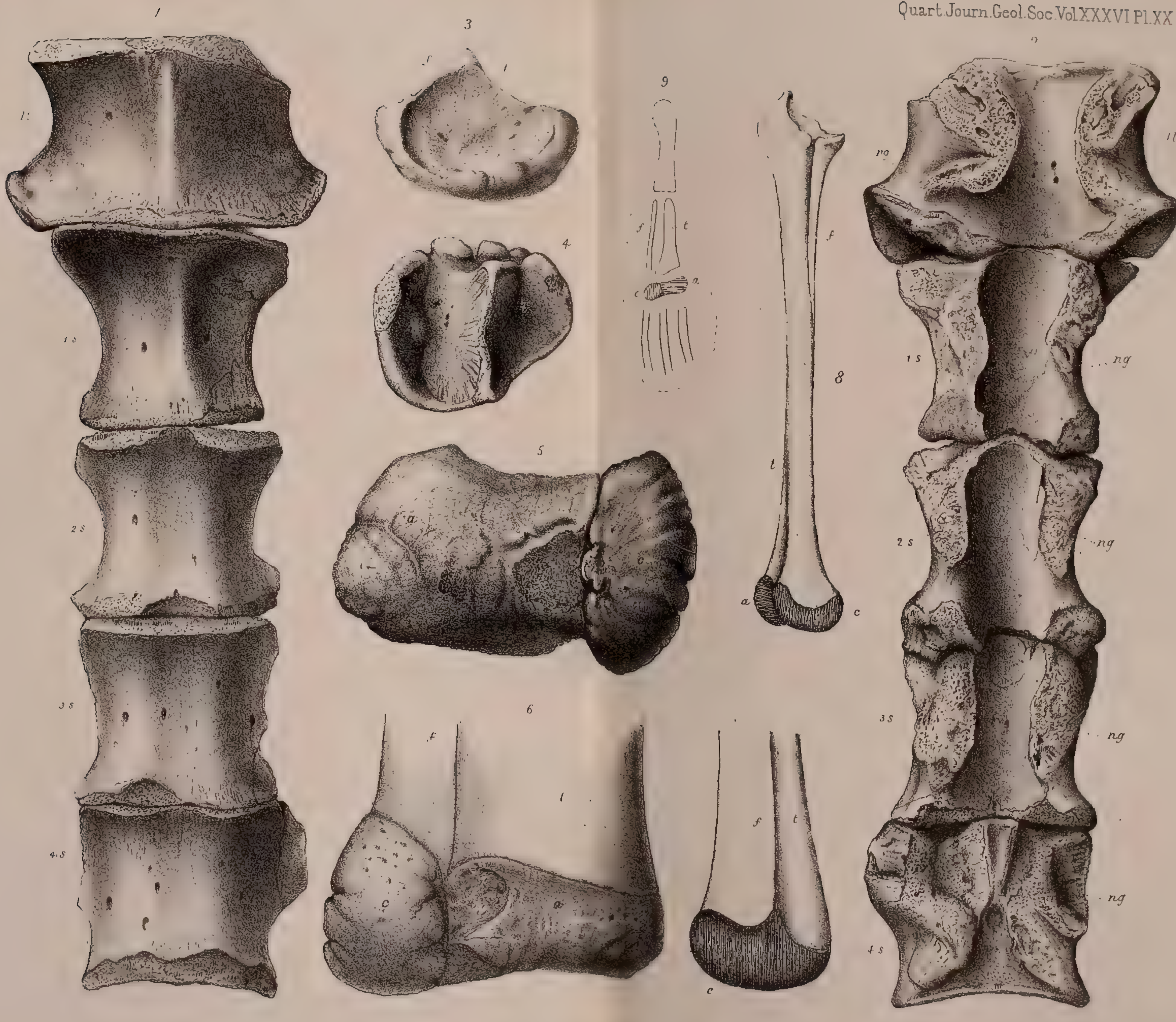
IGUANODON PRESTWICHII.



Berjeau lith.

IGUANODON PRESTWICHII.

Hanhart imp.



Berjeau lith

IGUANODON PRESTWICHII.

Hanhart imp

35. *The* Newer Pliocene Period *in* England. By Searles V. Wood, Jun., F.G.S. (Read March 24, 1880.)

[Plate XXI.]

In Two Parts.

Part 1, comprising the Red and Fluvio-marine Crag and the Glacial formations.
Part 2, comprising the Postglacial formations.

Part 1.

Stage I. *The Red and Fluvio-marine Crag.*

The movements by which the conditions of sea and land have changed in England from the time when the Red Crag began to form appear to me to have been so continuous that the formations from this point onwards can be studied with advantage only as one geological group; and as these have all accumulated during one great movement of depression and reelevation, the Newer Pliocene period seems to me the most suitable term for the lapse of time which they mark.

The commencement of this Crag in England is marked by the accumulation of those beds of which a small remnant is preserved in the cliff at Walton Naze. During its progress the continuous destruction of the antecedent accumulations of the same formation, as well as of the beds of the Coralline Crag, furnished that peculiar mass of comminuted shell of which the successive portions of the formation are made up. The character of the beds, and the highly and often continuously oblique character of the bedding, with other evidence on which I do not stop here to dwell, indicate that nearly all that part of the formation to which the term Red Crag (as distinguished from the part represented by the Chillesford beds) has been applied was accumulated between high- and low-water marks, when the rise and fall of the tide was considerable.

The Walton bed, as my father has shown, is destitute of many species of Mollusca which occur in the Red Crag of the northern (or Butley and Chillesford) extremity of the formation, while the beds occupying the intervening area afford some, though but slight, evidence of the horizontal transition between the two. These species are either those of Arctic habitat, or those which, having since become extinct, lived nevertheless into that succeeding period when the evidences of glacial conditions of climate become conspicuous. Now while this is the case with the fauna, it is important and confirmatory to find, as is the case, that though at its northern extremity (*i. e.* at Butley and Chillesford) the Red Crag passes uninterruptedly upwards into the Chillesford Clay, the reverse of this is the case at the southern (or Walton) extremity, if the bed of laminated clay, which there overspreads the Crag, be the Chillesford bed. In the former the Red Crag, gradually losing the oblique character, passes up by a series of horizontally bedded sands with molluscan remains (of which the uppermost part has been known as the Chillesford bed) into the Chillesford Clay. At Walton, however, the bed of sand passing up into laminated clay, with which the Crag s overlain, is not only unconformable to the Crag, but passes over its edge so as to rest on the London Clay. It is not clear to me now whether these beds at Walton represent the Chillesford Clay, or whether they may not represent the Contorted Drift; but if they do represent the former, then this clay into which the Butley Red Crag passes uninterruptedly upwards is as unconformable to the Red Crag of Walton as it is to the Coralline on which, in the neighbourhood of Butley, it also rests. Whichever way it may be regarded, there is no continuation of this southern extremity of the Red Crag into the Chillesford beds as there is of the northern.

North of the ridge of Coralline-Crag rock which, occupying the parishes of Sudbourn, Iken, and Orford in the south-east of Sheet 50, and of Aldborough in the south of Sheet 49 of the Ordnance Map (of which a diminutive reduction is given in Map No. 1 of the accompanying plate), bounds the marine portion of the Red Crag, there sets in the fluvio-marine portion, which ranges thence northwards nearly, but not quite, to the north of Norfolk in Sheet 68. This portion, I have for many years contended, is, as regards its lower beds, synchronous with that newer part of the marine accumulations which make up the Red Crag of Butley in the north-east corner of Sheet 48, and of the neighbouring parishes of Boyton and Chillesford, being altogether newer than the Red Crag further south, and which occupies the northern centre of that sheet. Nothing, however, so old as this fluvio-marine portion even the most recent part of it (the Chillesford Clay), occurs in my view along the North-Norfolk coast-section which extends through Sheet 68, such fluvio-marine beds as occur there containing *Tellina balthica*, a shell unknown from the Crag, and introduced by the commencement of the movements described in Stage II. The northernmost point at which the beds of this fluvio-marine part of the Crag (and these are the latest even of that part) are to be found is Aylsham, in the south-east of Sheet 68.

These facts appear to me to show that during the accumulation of the Red Crag there was a gradual movement of elevation in the southern part of the area occupied by that Crag, and of depression in the northern. By this the first accumulations represented by the Walton bed became land, and then successively the parts immediately to the north of it. As this took place the sea encroached at the northern extremity of Sheet 48, so that newer beds of similar foreshore oblique character formed over the parishes of Butley, Chillesford, and Boyton, containing a fauna so distinct from that of the Walton bed. These beds of Butley, Chillesford, and Boyton are bedded up against the principal remnant of the Coralline Crag which has escaped destruction from the waters of the Red Crag; and which destruction furnished so large a spoil of molluscan remains to the sands of the latter. On the north side of this remnant (the upper part of which consists of hard rock) the Red Crag assumes the fluvio-marine condition, which it maintains thence to its furthest northern extremity in Sheet 68. Of this, the lowest portion, *i. e.* the part precisely synchronous with the lowest beds of Butley, Boyton, and Chillesford, occurs only at Thorpe, near Aldborough, in the south of Sheet 49, in wells in the south-east of 50, and at Bramerton in the centre of 66.

Further depression then took place over this northern area, accompanied probably with further elevation of the southern. This carried the head of the estuary from Bramerton up to Aylsham, in Sheet 68, and also submerged the Coralline-Crag remnant which divided the fluvio-marine from the marine area—the result being that a sheet of laminated micaceous clay was deposited over both the fluvio-marine portion of the Red Crag and that part of the marine portion which was latest accumulated, viz. that of Butley and its neighbourhood, as well as over the Coralline Crag which divided the two areas. This sheet of clay having been first observed at Chillesford, where it overlies this newer part of the Red Crag, has gone by the name of the Chillesford Clay; and where either marine (as at Butley and Chillesford) or fluvio-marine conditions (as at Bramerton) had preceded it, this clay is separated from the Crag by sands. In the marine area at Chillesford these sands, horizontal in their upper part, gradually assume the oblique or foreshore character towards their base as they graduate into the highly oblique red foreshore Crag there. In their central portion these are full of valves of the estuarine mollusk *Scrobicularia piperata*, all detached; but in their upper layers, just under the clay, they contain the remains of Mollusca preserved by the tranquil accumulation of sediment afforded by deeper water, so that both valves of the Lamellibranchiata are united. Conditions exactly analogous prevail at Bramerton; for there the fluvio-marine Crag is overlain by sands of similar thickness to those with *Scrobicularia* at Chillesford; and in them at one of the Bramerton excavations that shell is common. These beds at Bramerton are succeeded by further sands just under the clay, and containing a bed of shells corresponding to the tranquilly preserved bed at Chillesford; and in this fluvio-marine conditions can scarcely be detected.

Between Bramerton and Aylsham this laminated clay not only becomes thin and more sandy, but the sands beneath it diminish much in thickness, and there is no fluvio-marine bed divided by sands from a more marine one as at Bramerton, but a fluvio-marine one only; and in my view this part of the Crag represents only the sediment of the estuary after it had, by the depression of its head, been pushed back northwards, and the Bramerton part of it had become marine, while the Butley foreshore had become submerged.

While the Chillesford sand and clay are thus the uninterrupted continuation, by slight submergence, of the fluvio-marine Crag of Bramerton and Thorpe by Aldborough, and of that newest portion of the marine Crag, they are not so of the oldest. As already mentioned, the Walton Crag is overlain by alternations of laminated clay and sand. The elevation of this in the cliff is between 50 and 60 feet; and at about the same elevation* at Hawks Mill, Needham Market, in the Gipping valley, six miles N.W. of fig. I. A, I found a section of highly micaceous laminated clay passing up into micaceous sand†. If this be not the Chillesford Clay, then I think we may infer that the laminated deposit, unconformably covering the Walton Crag is not that clay either, and that this and the rest of the southern part of the Red Crag remained in the state of land; but if it be, then the depression described carried the sea not only over the Walton bed, but also up the Gipping valley, though by what route, unless the intervening area was submerged, is not apparent; for, with the exception of the two patches at Walton and Needham, not a vestige of the Chillesford Clay or sand occurs south of Butley, although the Red Crag ranges south of that place for twenty miles. The Red Crag between the Deben and the Orwell attains, even in its unaltered condition, *i. e.* with shells, to an elevation of nearly 80 feet at one place (Bealings), and still higher at another spot near Sparrow's Nest, three quarters of a mile north of the line of fig. I. A (where it was erroneously shown as a boulder in the sections of the 'Introduction to the Crag Mollusca,' Supplement); but generally, in both this and in its altered or decalcified condition of red sand, occasionally containing casts of shells, it lies at and below 60 feet, being overlain, without any distinguishing line‡, by from 20 to 30 feet of the yellow sand marked *?* in fig. I., which seems to me to be a continuation of the Lower Glacial sand *b 1*. Throughout its range from this limit northwards the base of the Chillesford Clay, however, though from the deeper water of the estuary in that direction it descends to Ordnance datum on the coast in the north of Sheet 49, never exceeds, and, I think, nowhere quite reaches, an elevation of 50 feet, which is about that of the patches at Walton and Needham; and the molluscan remains preserved in the uppermost beds of the Crag thus overlain show no transitional character to connect them with the shell-bed just under the Chillesford Clay, as do the upper beds of the Red Crag at Chillesford and Butley. If, therefore, this clay overspread the intervening area, it doubtless did so unconformably to the Crag of this part, as it does at Walton; and possibly the highest eminences of this, such as those at Bealings and Sparrow's Nest, were not covered by it. However this may have been, the Chillesford Clay seems to have been completely removed over nearly all the marine part of the Red-Crag area; and this I infer can only have taken place by the waters of the Lower Glacial sea under which the sands *b 1* accumulated, and which sea, removing this clay, covered with its sands the chief part of the south-east of Sheet 50, as well as the extreme north-east of 48,

* All the elevations mentioned in the paper have reference to Ordnance datum.

† This had its laminæ at one end turned up to the vertical, evidently by that pressure of the ice, during the later part of the Chalky Clay, which gave rise to the features described in Stages III. and IV.

‡ As to this see the remarks as to Wilford-bridge section in Stage II.

where they surround islands of the Chillesford Clay, and form, as described in Stage II., the chief part at least of the sands of Dunwich Cliff.

The limits of the Crag estuary in Sheet 66 can be traced with much approximation to truth. In fig. IX., drawn through the fluvio-marine Crag and Chillesford Clay at Thorpe by Norwich, these beds occupy a higher level, and have a greater thickness of chalk intervening between them and the datum-line than is the case at Bramerton, two miles to the south-east. The Crag also is thinner and all of it is fluvio-marine, the division into a fluvio-marine bed below and a marine one above (which exists at Bramerton) not obtaining here for the reasons already explained; and this part of the Crag is therefore more nearly synchronous with the marine than with the fluvio-marine part of the Bramerton section. To the north-west and west of fig. IX. large excavations occur in which both the Crag and the Chillesford Clay are absent, and the chalk, rising to a proportionately higher level, is overlain direct by the sands *b1*. From this it results that the slight depression which extended the estuary in the way already described did not suffice to submerge the site of Norwich or the area to the north-west of that city, no trace of either *a1* or *a2* occurring in that direction, and the chalk also rising westwards. One head of the estuary having been carried by this depression northwards up to Aylsham, a branch was in the same way carried past Norwich southwards for several miles, coinciding apparently with a valley which, in the condition resulting from the manifold changes treated of in this memoir, is now represented by that of the Tese, the northern branch being similarly represented by that of the Bure. This branch was probably divided by land from the head of an arm of the earlier part of the main estuary which stretched up past Bungay from the south; and in it both the Crag and Chillesford Clay are but thinly represented, the former passing sometimes, near the head of the valley about Saxlingham, into shingle, and the clay which overlies it presenting but a small admixture of mica. The Crag-shingle at Dichingham House near Bungay is full of the Crag shells; but at Saxlingham I was informed that mammalian remains only occurred in it.

The river which fed this estuary with the mud from which the Chillesford Clay resulted must have flowed from some region of mica-schist or of granitic rock, and most probably, therefore, from North Britain. At the base of this clay in Easton Bavent cliff (north-east of Sheet 49) I observed rolled chalk, similar to that which is so abundant in the Cromer Till (*b2*), to be imbedded, and the clay in this part to be occasionally contorted slightly. This shows that glaciers had at this time begun to grind down the chalk-country, and to discharge their moraine into some arm of this river; and as North Britain, by reason of its latitude, would be proportionately more glaciated, it seems most probable that the profusion of mica which characterizes the clay was produced from the grinding of these rocks in North Britain by the ice, which by this time had enveloped the northern part of the kingdom, and terminated in the principal branch or branches of this river. The preglacial valley through which this river flowed from North Britain appears to me to have been that in which the town of Cromer stands, and in which the greatest thickness of the beds described in Stage II. have accumulated. At the time of the Crag this part of it stood higher than now, its slope having been changed by the depression that introduced Stage II., the relative height of the area in the south-east of Sheet 68, and the adjoining parts of 66 and 67, having also been changed by the same cause, and by the great reversals of inclination which England underwent during the period examined in this memoir. The gentle slopes of this valley have, however, remained unaltered by these movements for some miles on either side of Cromer; for while beneath that town the chalk sinks to low-water mark or below it, it rises from there gradually both to the east and west, so as to attain the beach-surface above high-water mark about four miles to the east and two and a half miles to the west of the town. On the surface of this flat valley of chalk grew the vegetation which has long been known as the Forest-bed; and in swamps, meres, or tributary streams there were accumulated the clays with land and fresh-water Mollusca and mammalian remains associated with it. These beds are thus, in my opinion, of Crag age, and the mammalian remains preserved in them those of the Mammalia which then inhabited England—all those remains found in the Crag itself, even the fluvio-marine portion, or most of the latter at least, being derivative and belonging to inhabitants of some period or periods antecedent. The clay with mammalian remains, which has its surface penetrated by roots, and out of which a hollow has been scooped and filled in with a laminated freshwater deposit, containing at its base a bed of *Unios* at Kessingland and Pakefield Cliff (north of Sheet 49), and which is there overlain directly by the Middle Glacial (*c*) and the Chalky Clay (*d*), is not of the same age; and though mammalian remains from it have, by the use of the term "preglacial forest-bed," been confounded with those from the beds just mentioned, this freshwater and mammaliferous formation is later than the Crag, since it occupies a valley scooped through or out of the Chillesford Clay, and at one end of this it rests on that clay*. The eastern side of the original Crag valley in which these forest-beds of Crag age thus accumulated extends from Cromer nearly to the south-eastern extremity of Sheet 68; for to that distance these beds show themselves along the coast beneath the formations of Stage II. Very near to this extremity these formations, thinning much, sink below the beach-line, and the further extension of the forest-beds becomes concealed; and though the Contorted Drift rises above the level of the sea here and there in the interval, it is not until the north of Sheet 67 is entered that this formation rises to any height above Ordnance datum; but, as it does so, the cliff, which should present a section of it, overlain by the Middle Glacial and the

* See Section of this cliff by Harmer, Quart. Journ. Geol. Soc. vol. xxxiii. p. 134.

Chalky Clay, is hidden by blown sand, and the extension of these forest-beds there cannot in consequence be detected. At Hopton and Corton Cliffs, however (about the centre of Sheet 67), it is said (for I have not personally been fortunate enough to meet with the base of the cliff sufficiently cleared of beach to see them) that they reappear immediately under the Contorted Drift shown in fig. XIII. The earlier beds of Stage II. being here absent, there is nothing to show the age of the forest-remains of this part beyond their priority to *b3*.

During this stage we find no indication of the presence of the sea over any other part of England than the south-eastern part of Norfolk, the eastern part of Suffolk, and the north-eastern part of Essex. From sections discovered by the Survey the marine area appears to have stretched up the Stour valley to Sudbury.

Stage II. *The Lower Glacial beds.*

The movement giving rise to the beds of this series was one of depression, apparently not continuous, but broken into two movements, of which the first was, compared to the second, of no great extent. This first movement of depression, extending in an increasing degree over northern Norfolk, seems to have been accompanied at the outset by elevation in north-east Suffolk, so that a part of the laminated clay, forming the latest accumulation of Stage I., was converted into land, giving rise, at Kessingland and Pakefield, to the terrestrial surface on which the mammaliferous clay, with its surface penetrated by roots, and the laminated bed with *Unios*, already mentioned, were formed, and which are overlain directly by the gravel, *c*, and the Chalky Clay *. At points to the south-west of Kessingland Cliff—viz. at Henham in the north of Sheet 49, and at Halesworth (on the Blyth river) in the north-east of Sheet 50—we meet with very clear evidence of a conversion of a part of the Chillesford Clay into land at the close of Stage I.; for at these places there occur pebble-beaches, from 25 to 30 feet thick, bedded up to foreshores or even low cliffs of this clay. The shingle of these beaches is bedded at the angle of terrestrial repose, not, as in the Red Crag, in successive beds of oblique stratification, where sand and shells thrown up as banks have been planed off again and others heaped over them, but in one continuous oblique slope throughout the 25 or 30 feet, their section presenting in this respect that which the Chesil Bank, or any other great shingle-beach, would do if cut at right angles to its trend. West and north of this beached shingle the pebbles of which it is formed spread out in seams interstratified with sands that are red or orange-coloured at base, and become lighter in colour upwards. These, in many places, rest on the Chillesford Clay, but in others have taken its place. Where they rest on it the junction is marked by a strong line of erosion which indents the surface of the clay; but in some places in the valley of the Bure—that

* See Harmer, *loc. cit.* The view taken by that gentleman and myself, that this bed may have intervened between the Contorted Drift and the gravel *c*, is untenable in view of the case as traced in this present memoir.

is to say, along the line by which the Crag river entered its estuary—this division is, as I shall presently explain, obscure. These pebbly sands I brought to the notice of geologists in 1866 * under the title of the "Bure-Valley beds," from the circumstance that they yield molluscan remains in that valley. They were a few years after this described by Professor Prestwich, in his memoir on the Red Crag †, and by him called "the Westleton shingle." In the south-east of Sheet 66 also these pebbles are heaped up into banks for some miles on the east of Loddon; but the banks are not oblique-bedded, and are therefore, I infer, altogether of submarine accumulation. Here at Loddon, as also in fig. IX. and generally over Sheet 66, these pebbly sands are overlain by the Contorted Drift, *b3*; but along the coast-line stretching through Sheet 68 another formation, the Cromer Till, *b2*, intervenes. Here, and thus overlain by *b2*, the sands rest on the chalk or, where such are present, on the terrestrial formations of the Crag already described. Where they rest on the chalk, at Weybourne, they contain at their base Mollusca, of which the bivalves have often their valves united, showing that they lived there; and at Woman Hythe, two miles west of Cromer, they contain in their upper part, near where they pass into *b2*, *Mya truncata*, preserved with valves united, and in the position in which the animal lived. They also yield Mollusca at Belaugh, Rackheath, and other places in the north-east of Sheet 66, which here, as at Weybourne, also show a fluvio-marine character. They have been divided into two beds by Mr. Clement Reid, who alleges that they are separated by a land and freshwater bed, extending, so far as traces of clay with land and freshwater shells afford an indication, along the base of the cliff. These traces are, in my opinion, merely the result of the transport by the shore ice (formed in rivers that discharged into this bay or estuary) of portions of the mud-flats and banks of those rivers to which it froze during winter ‡. The only foundation that I can find for such a view as that of Mr. Reid is that the small boss of peaty clay with freshwater Mollusca which shows itself for a few yards above the beach at Woman Hythe, and which is overlain by these sands containing *Mya truncata*, has a few feet of sand with *Tellina balthica* and other marine shells between it and the chalk. This mass of peaty clay, however, is of so limited an extent and thickness as to be quite within the power of such ice as forms in the St. Lawrence, and there transports huge rock boulders along the gulf of that river, to carry; and as I observed a mass of similar peaty clay (though without shells) of equal dimensions imbedded in the Till itself on the east of Cromer, and strips or sheets of chalk of yet larger dimensions are interstratified in the Till just over this mass of peaty clay, such may have been the origin of the bed in question, so far as its position in these sands is concerned. As these sands extend eastwards through Sheet 68, they become, in places, charged with carbonaceous débris, derived, in my view, from the spoil of the swamps and river-banks represented by this peaty

* Quart. Journ. Geol. Soc. vol. xxii. p. 546. † *Ibid.* vol. xxvii. p. 452.

‡ See footnote*, p. 523, for similar evidences during Stages III. or V.

clay, swept by the severe conditions of climate now approaching into the waters of the sea I am now tracing. In the extreme east of Sheet 68 they thin out to very insignificant thickness before disappearing under the beach-line; and as we approach the mammaliferous and freshwater bed of Pakefield and Kessingland they disappear, setting in again in the condition of beached pebbles and of sands, interstratified and intermixed with pebbles for several miles south of those places, whence southwards to the north-eastern end of the line of fig. I., and over that line also, the pebbles are absent. The Mollusca of these sands are given in the tabular list to my father's first Supplement to the 'Crag Mollusca' in the volume of the Palæontographical Society for 1873, in the column headed "Lower Glacial;" and to these the researches of Mr. C. Reid have added a few species more, most of which are given in the list accompanying the second Supplement. From a familiarity with the character of purely aqueous deposits, we have long recognized that the unconformable stratification which results from false bedding is due to current action; but our knowledge of the effect produced by the extrusion of morainic material from a glacier which terminates beneath the sea is as yet hypothetical; nevertheless I believe that the divisions of upper and lower Till separated by sands in this formation of the Cromer coast, which have been made by Mr. Reid, have their origin in the irregular and intermittent extrusion into the sandy and silty sea-bottom, at the commencement of the stage we are now considering, of material from the land-ice, which having been in existence, as already shown, in the upper waters of the Crag river during Stage I., had by the northerly subsidence of Norfolk which I have described, and by the augmentation of the cold, not only reached the sea in England, but had entered the limits of Norfolk and Suffolk. This material was, in some cases, carried into and interstratified in these sands, and in others pushed over them. Instances of both methods appear in the coast-section of North Norfolk, and in the (chalk) pit at Guist crossed by the line of fig. VIII. On no better foundation that I can see have similar divisions of one continuous glacial accumulation been made in other districts and other countries, and a theory of a cycle of alternations from warm to cold climates during the Glacial period evolved to account for them.

Such, in my opinion, was the origin and mode of accumulation of the pebbly sand and Till as one formation, the structure of which has been greatly obscured by the churning-up which, in common with the Contorted Drift that overlies it, this formation has undergone, as presently described. Towards the western extremity of the coast-section in Sheet 68, viz. at Weybourne, this churning-up has not taken place; and there the Till and the Contorted Drift cannot be distinguished, and appear to be one continuous accumulation, of which the base is distinctly interstratified with the pebbly sand. At the opposite extremity of the coast-section, a distance of only 14 or 15 miles, this churning-up also ceases; but there the Till, or what may be considered as representing it, is separated, in the clearest and most marked manner, from the Contorted Drift (*b3*); for this drift, in the form of a strongly stratified silt with bands of clay full of rolled chalk, rests altogether unconformably on a formation (the Till) consisting of dark sandy unstratified clay with worn specimens of *Tellina balthica* and fragments of *Cardium* and *Cyprina*, the surface of which clay is worn into hollows in which sands are bedded, which, with the clay thus worn into hollows, have alike been planed off level to receive the stratified silt of the Contorted Drift. This marked break or unconformity continues for 2 or 3 miles until the lower bed disappears under the beach-line, while from this condition of highly stratified silt, *b3*, gradually changes horizontally south-eastwards along the cliff until it disappears beneath the beach towards Eccles into that reddish-brown, unstratified, or obscurely stratified, brickearth which I have described as having so general an extension over the pebbly sands in Sheet 66, and as making its appearance again above the beach-line beneath the Middle Glacial and Chalky Clay in the north of Sheet 67*.

Before, however, tracing the southerly extension of the Contorted Drift, and of the pebbly sand and Till, I should point out that the difficulty to which I have adverted in detecting a definite line of division between this sand and the Chillesford Clay in some parts of the Bure valley, while this line is so marked elsewhere, seems to be just what we might expect to occur under the circumstances detailed; for as the depression of the valley of the Crag river took place, while elevation to the south-east occurred, and the sea made its way into the depressed area, the river yet existing further north still brought the micaceous mud, so that this at the first and until the new conditions were established became interstratified with the sands which continued to form within what remained of the former estuary, and in the area newly occupied by the sea. Though seams of this micaceous mud thus occur in the pebbly sands of this part, and physically the sands of the latter part of Stage I. are here difficult

* This unconformity is shown in Nos. I. and II. of the sections accompanying the Introduction to the 'Crag-Mollusca' Supplement. I would take this opportunity of correcting some of the sections given in that Introduction, viz.:—The bed 8 of Section A and Section P represents both that marked ? and that marked *c* in fig. I. of the present memoir. The bed 8, north of Thorpe in Section B, and south of Westleton in Section C, is probably the sand *b1*. The Red Crag shown as detached at the Sparrow's Nest in Section P is probably the Crag *in situ* rising, as described in Stage I., to high elevations. In Section R the bed 10, where capping the lowest part of the cliff, is the Contorted Drift, consisting of brickearth with patches of Chalky Clay in it, but where capping the highest, consists of this and of a bed of shingly gravel beneath it. The very small patch of 9 over which both these passed (and which I now regard as a remnant of the Till, for it graduated into 8, while the brickearth 10 is unconformable to 8) seems to have disappeared by the waste of the coast; and 8″ 8‴ and 8‴ are the sand *b1*, No 6 being either this sand as represented there or the Crag. In Section S, though the small patch numbered 7 remains, I am told that the larger one, which extended from the north of Easton to the south of Covehithe Cliff, has disappeared by the rapid coast-waste that has gone on since I drew the cliff in 1866. The bed marked 8 in Sections XIX. and XX., and that marked ? in XVII., is the sand representin g decalcified Crag.

of separation from the sands of the present stage, yet palæontologically there is a very clear and satisfactory test for their distinction in the fact, to which I first called attention 16 years ago, that wherever the pebbly sands are fossiliferous they yield *Tellina balthica*, and in abundance, while this shell is absolutely unknown in any bed of Stage I. The researches of collectors during this time have fully confirmed my statement, while the one or two cases where this shell had been given in publications as from localities in which beds of Stage I. only occur, or at least yield fossils, have been investigated, and been proved to have arisen from clerical errors. The introduction of this shell having taken place so abruptly and in such profusion, it seems evidently to have been due to the northerly depression which I have described opening a communication with a part of the sea nearer the Baltic, where this mollusk had lived during the Crag, but from which part some geographical cause had hindered its migration into the waters of the Crag of Suffolk or Norfolk, or into those of the Crag of Belgium, in the beds of which it has never been met with. In every marine bed of the North-Norfolk cliff, from the chalk surface upwards, however, this shell occurs, and it characterizes also all the formations posterior to these wherever they are fossiliferous.

In tracing the beds of the Stage I am describing southwards from Hopton and Corton Cliff, which is the point furthest south at which we find the Contorted Drift exposed in the coast-section with the identical characters presented by it where lost by descent below the beach-line in the south-east of Sheet 68, we come, after passing the freshwater beds posterior to the Crag, overlain, in Kessingland and Pakefield Cliffs, directly by the gravel *c* and Chalky Clay, to the low cliff of Covehithe and the two low cliffs of Easton Bavent (all in the north of Sheet 49). These are all formed by the Chillesford Clay in its greatest thickness, overlain by the red and orange-coloured beds belonging to the lower part of the pebbly sand—the uppermost sands of the Crag, which are white and full of shells, coming up under the clay only in the central one of these three cliffs. At the south end of the southernmost cliff of Eastern Bavent the Chillesford Clay has been cut away, and its place taken by the pebbly sands, so that from this point southwards to the point where the north-east extremity of the line of fig. I. begins these rest on the fluvio-marine Crag, and form the whole or, at any rate, the upper part of the sands of Dunwich Cliff*. In the south-west of Sheet 68 the beds of the Cromer Cliff, in the full thickness possessed by them in that part of Norfolk, are cut through by the valley of the Wensum, down which during emergence came the Chalky Clay as in fig. VIII.; and in this part also we meet with sections showing the unconformability between the Till and the Contorted Drift. Fig. XVI. is taken from one of these, near Yarrow House, Guist (1½ mile south of the line of fig. VIII.), and

* See last note for the correction of the representation of this Cliff (as Sect. R) given in the Introduction to the 'Crag-Mollusca' Supplement.

in it the Till, consisting of unstratified sandy clay full of small worn flints, differing in colour and in the absence of shell fragments, but in other respects similar to that at the base of Hasboro' and Bacton Cliff, is unconformably overlain by highly stratified chalky silt, just as it is in that cliff. The intervening hollows filled with sand at Hasboro' and Bacton, however, do not appear here.

Sections at and near Snape, in fig. I., several miles south of Dunwich, show clay or loam exactly similar to that thus capping Dunwich Cliff, resting unconformably on remnants of the Till larger than the scrap which has now * disappeared from Dunwich Cliff, and which (as it did there) consists of stratified chalky clay. These remnants occur along the edge of the low plateau forming the north side of the Alde valley; and pits in two of them are touched by the line of fig. I., in one of which, at Aldringham Green, this stratified clay was overlain by several feet of red, close-bedded gravel (*c*). The clay here was very sandy, and its stratification was all arched, as is that of the Till about Trimmingham (on the coast in Sheet 68), and it was similarly full of interstratified chalk. From the point where the sands *b1* take the place of the Chillesford beds in Easton cliff, they stretch southwards through the central part of Sheet 49 and corresponding part of Sheet 50 until we encounter this clay again, abutting, along with the uppermost part of the fluvio-marine and marine developments of the Red Crag, against the islands of Coralline-Crag rock presently to be mentioned, and over which the Chillesford sand and clay (but not the marine or fluvio-marine Crag) were spread at the end of Stage I. Where the Chillesford Clay shows itself on the north of these islands, *i. e.* at Aldboro', the sands *b1* rest on and indent it. Thus the heaths of Walberswick, Dunwich, and Westleton, which in the map to the Introduction to the 'Crag-Mollusca' Supplement are represented as occupied by the Middle Glacial (*c*), consist almost entirely of the sand *b1*; and as the chief part of these heaths are above the junction-line of the Middle Glacial gravel (*c*) with the Chalky Clay, and so formed islands in map No. 2, there is but little of this gravel over them.

Mr. W. H. Dalton, of the Geological Survey, who has mapped this area, recognizes the distinction of this sandy and often stratified chalky clay, which I have just referred to the Till from the Great Chalky Clay of Stage III.; and thus we find the sea-bed of the earlier part of the Stage I am now tracing, which is represented by the sand *b1*, passing up, both in North Norfolk and in East Suffolk, into the earliest bed in the formation of which the direct intrusion of morainic material has played the predominant part, viz. that distinguished as *b2*; for both in places along the North-Norfolk Cliff and inland, as at Guist chalk-pit, the material of the Till is distinctly interstratified in the sand. In the Cromer Cliff at Trimmingham, at Runton, and at Weybourne, the material of the Till is interstratified with the sands, so that the latter, as also in some instances seams of pebbles, lie above as well as below it, and this interstrati-

* See footnote, *antè*, p. 466.

fication is followed by the main mass of the Till reposing more irregularly upon the uppermost sand layers or pebble bands.

The extent to which the sand *b1* covered the Red-Crag area, as discussed in Stage I., is obscure; because the yellow stratified sand, marked *?* in fig. I., seems to pass down into the red loamy sand which, from its occasionally containing indurated bands with casts of shells, can be recognized as the Red Crag altered, and to some considerable extent restratified also by the decalcifying agency of rain-water. This yellow sand at the great scarp at Wilford Bridge (shown in fig. I.) overlies an irregular surface of the red loamy sand, and occupies depressions in it, so that but for the bands of stratification running through both sands in common they would appear as distinct formations. As the decalcifying action has, however, extensively produced apparent restratification by rearranging the soluble ferruginous and argillaceous materials which by their colour give rise to the bands of stratification without changing the position of the insoluble residuum of sand grains, I think that these red and yellow sands, thus apparently stratified as one, are nevertheless distinct formations, and that the upper of them represents the southerly extension of the sand *b1* as shown in fig. I.; for the abrupt cessation of the Chillesford beds at Chillesford and Butley, and their overlay at the latter place and at Aldboro' by this sand, seems to me inexplicable otherwise.

This yellow sand is overlain by and, for aught that is disclosed to the contrary, appears to pass up into the finely stratified brickearth marked *b3* in fig. I., which is more than 50 feet thick, and contains chalky silt, chalky grit, and thin bands and patches of chalky clay similar, except in the smallness of the chalk lumps, to that of Stage III., and which in this respect so resembles the Contorted Drift at Weybourne on the North-Norfolk coast. The remnants of this brickearth which have escaped destruction from the denuding action of the sea during the rise of England in Stage III. are in the north-east of Sheet 48 considerable, and they formed shoals and islands during the later part of that Stage as shown in map No. 2; for they extend beyond the line of fig. I., another island of this brickearth overlying the yellow sand at Kirton and Trimley, 6 miles to the south-east of the line in that figure. Nowhere, however, do we get any thing beyond wells such as that at Kesgrave, which, after passing through 50 feet of the brickearth (the actual excavations in it having stopped at 40), entered the sand, to show the precise relation which it bears to the sand beneath*; but every thing points to its being a continuation of that sand by change of sedimentary deposit. The submarine extrusion of moraine to which the Till owes its origin does not appear to have reached so far as this part of Suffolk; but the clayey and chalky silt which issued from the ice bottom was here thrown down in the form of finely stratified brickearth, and in the place of the sand previously accumulated there; while the material of the chalky moraine was

* At Hasketon it appears to contain and be underlain by gravel beds, as does the Contorted Drift shown in fig. XV. and that capping Dunwich Cliff.

occasionally rafted by field-ice and dropped so as to become interstratified in it. The rise of the sea-bed at the commencement of the gravel *c* and Chalky Clay caused much of this brickearth to be washed away by currents, so that channels were eroded through it, and in these the gravel *c* accumulated, as the Cromer Cliff so conspicuously exhibits, especially towards its eastern extremity. Thus, though from its identity *mainly* with the Contorted Drift which overlies the Till along the Cromer coast I have designated it all as *b 3*, this brickearth in the western part of fig. I., probably in its lowest part, represents also the Till itself, the break occurring between these beds or between *b 3* and *b 1*, from Bacton Cliff in Sheet 68 to the Alde, disappearing in this part of Suffolk, while still further south all gives place to the gravel *b'*, as presently to be shown. Drift ice carrying portions of the moraine extruded in shallow water or on the shore (as occurs at places in Greenland), and dropping it, has doubtless been the means whereby the bands of chalky clay just referred to have become interstratified in, and patches of it irregularly scattered through the brickearth. This is especially the case with this brickearth from Cromer to Weybourne, where it is also largely made up of streaks of chalk silt. At Blaxhall (in the south-east of Sheet 50, and 3 miles west of the line in fig. I.) it contains marl masses similar to those in the Cromer Cliff.

It is clear to me that the ridge of Coralline-Crag rock which had divided the fluvio-marine from the marine area of the Red Crag, and been overflowed by the waters of the Chillesford Clay, became, from the resistance which its hard mass offered to the denuding waters of the sea again invading this region at the commencement of Stage II., an island in them, or more probably, as it is divided by the Alde, two islands; and that the soft Chillesford beds which had been spread over this ridge, as well as the uppermost (or *Scrobicularia*) beds of the Red Crag which lay up against it or on its flanks, were, save on this ridge and in its immediate vicinity, everywhere else in the north-east of Sheet 48 and south-east of Sheet 50, swept away; so that the sands *b 1* were here laid down on the lower beds of both the marine and fluvio-marine portions of the Red Crag and bedded around these islands. The remnant of these soft strata thus preserved by contiguity to this rock, and forming a promontory to the southern of these two islands at Chillesford, is traversed by the line of fig. I. at that place, and that also which formed a similar promontory to the other island is traversed by this line at Thorpe by Aldboro'*. A tract of the same beds at Butley, half a mile wide by one and a quarter long, formed a third island, divided from the section by the Butley Creek. Beyond this south-westwards no trace of the *Scrobicularia*-Crag or of the Chillesford beds has been left until we come to the beds capping the

* After the Plate had been photo-lithographed I found that by having confused the locality of the section at Snape with that of one in *d*, to the north-east of it, two miles of country had been omitted from the line of fig. I. This renders the line there tortuous.

Red Crag at Walton Naze and the section at Needham referred to in Stage I.

It thus appears that during or after the accumulation of beds *b 1* and *b 2*, but previous to or coincidently with the setting in of the great submergence of England during which the brickearth *b 3* was formed, a disturbance of the Lower Glacial sea-bed took place, which caused the denudation of *b 1* and *b 2* over the area between Sheets 68 and 48.

The masses of marl imbedded in the churned-up mass of the Till and Contorted Drift in the Cromer Cliff appear to me to have had their origin and been thus introduced at the time when, from increasing submergence, and particularly from the augmentation of this in the westerly direction, the ice retreated from the position which it occupied during the formation of the Till, to take a new direction to the sea, in accordance with the altered inclination, as detailed in the sequel. In consequence of this the ice which had issued through the Humber to form the Till retreated to the top of the chalk Wold, terminating in the sea where this Wold is lowest, viz. in South Lincolnshire, and where a vast accumulation of reconstructed chalk, so pure as, like these marl masses, to be burned for lime (and which is shown as part of the Chalky Clay in map No. 1), lies up against the chalk *in situ* in Sheets 83 and 84. This forms a range of hills as high, or nearly so, as the Wold itself in that part; and out of it the Bain-Steeping trough referred to in Stage IV. has been excavated, this marl forming one side of that trough and the chalk the other, and at the head of the trough forming a plateau which is continuous with the Wold-top. Bergs breaking from the ice thus terminating, carried masses of this accumulation into the sea and over North Norfolk.

The masses of marl thus introduced into the Contorted Drift of Norfolk are, in the north of that country, excavated both for agricultural purposes and for lime-making; and their position in the Cromer-Cliff section appears to me to show that for the most part they were not introduced until near the termination of the bed *b 3*, and to have in some cases sunk or been forced through this bed. So far as the pall of *d* does not conceal them, I have shown them in fig. VIII., and have endeavoured there to convey some idea of the manner in which, as seen in the cliff itself, they occur and are connected with the contortions. They vary much in character, never consisting of pure unaltered chalk, such as is imbedded and sometimes interstratified in strips of considerable thickness in the Till, but present all gradations of glacially reconstructed material, from shattered chalk, with disturbed flint and galls of clay, to removed and transported Contorted Drift itself. They mostly consist of material which is undistinguishable from that part of the Chalky Clay which I have just described as abutting in thick mass against the Lincolnshire Wold in Sheets 83 and 84. Sometimes in the inland sections in the south-west of Sheet 68 they consist of finely stratified chalk silt, passing from a white to a pale lavender colour, and splitting up into laminæ as fine as paper. In some instances equally large masses of gravel have been forced into the brickearth, giving rise to contortions in a similar way to the masses of marl. So far as these masses are found in North Norfolk, so far only, whether in the cliff section or inland, do the great contortions extend; for beyond this area contortions are rare and of trifling extent, and are due to other causes. The introduction of these masses and the formation of the contortions (which, as before observed, are not confined to the upper part of the Lower Glacial formation called *par excellence* the "Contorted Drift," during the accumulation of which they originated, but often extend down to the Lower or Blue Till part, the sand (*b1*) at the base of it being in some cases even squeezed out) have evidently been the result of grounding bergs. These were of the kind called by Nordenskiöld false bergs, which he describes as large fragments that fall from the perpendicular face of lofty ice which enters the sea on a shore of easy slope and in water of moderate depth, as distinguished from true bergs, which are far larger fragments of a glacier which enters the sea through a narrow, deep, and steep-bottomed fiord, and from which they are lifted and floated off by the buoyancy of the water*. The ice at the time of maximum submergence resting thus on the chalk Wold, and terminating in the sea there in the former manner, the moraine which it formed being chalk, with the slight intermixtures just described, was extruded into water of no great depth, while deposits of a finely laminated character were thrown down from the copious supplies of chalk silt borne out by the freshwater streams that issue from beneath the sea-faces of glaciers. The same silt, carried further, was in that part of Norfolk which extends past Cromer to Weybourne extensively interstreaked and intermingled with the brown mud forming the brickearth of the Contorted Drift, its quantity increasing palpably in the direction of the Lincolnshire Wold. A mass of ice breaking off from the vertical face of this glacier being of so nearly the same specific gravity as water, and most of it falling from a height, would enter the water with force sufficient to carry it to the bottom, which was not deep, and also to force its jagged surface into that bottom, whence rising it would lift portions proportional to the size of the berg and to the force with which it fell. Drifting towards East Norfolk, where the submergence was least, these bergs passed to shallow water, so that they grounded, churning up the soft bottom there; and as they melted they left whatever they carried, which in most cases was part of the bottom, which they scooped up as they fell from the glacier. Sometimes, however, where the bottom was gravel, they have, in floating off again, carried away portions of this, and grounding in Norfolk have forced this into the deep and soft bottom formed of *b2* and *b3*, and even removed and reintroduced portions of these beds themselves, so as to cause perplexing interruptions to the continuity of the stratification in the coast-section. The disappearance of these masses and contortions as these beds thin off east of Mundesley, in the coast-section of Sheet 68, especially when regarded in connexion

* Geol. Mag. vol. ix. p. 363.

with the easterly diminution in the submergence described in the sequel, shows clearly that in this direction the water became too shallow for the bergs to pass further; but the water deepening, as we shall see, southwards, some passed in that direction, so that the marl masses are imbedded in *b3* at Blaxhall, in the south-east of Sheet 50; and were not the intervening space almost all concealed by the pall of *d*, they would probably be found there also.

Brickearths anterior to the Chalky Clay are noticed in the Geological Survey Memoirs as occurring in the north-west of Sheet 64; and Mr. Harrison, of the Leicester Museum, informs me that the beds of Stage III. are at Oadby, in the north of Sheet 63, underlain by a bed of brickearth; but with the exception of a brickearth with beds of gravel containing derived specimens of the Portlandian *Ostrea expansa* at Stevenage (in Sheet 46), which I regard as *b3*, no clear evidence of the Contorted-Drift brickearth is to be found south of the Stour river, but in lieu of it beds of gravel range to great elevations all over the south of England; and these I propose now to trace.

Southwards from the point at which this Drift ceases we find gravel extending from the bottom to the top of Danbury Hill, and crowning it at an elevation of 367 feet, as is the case with the Tiptree ridge (shown in fig. VII.), a few miles to the north of it, and of which the elevation is less. The highest hills in the south of Sheet 1 are formed of outliers of the Lower Bagshot, ranging at elevations of from 300 to upwards of 400 feet; and on these there is generally no gravel but that of pebble-beds (marked viii. in fig. VI.), which are either of Bagshot or, more probably, of Diestian age. Nevertheless these were evidently once covered with this gravel; for on one of them, that of Warley, at the elevation of 370 feet, I found a patch of it a few feet thick, exposed in digging the foundation of a house. It was composed of large subangular flints, of smaller flints, of the Diestian pebbles (probably also of Lower Tertiary pebbles), and pebbles of quartz, quartzite, and sandstone. Billericay Hill, in fig. VI., being identical in its position relatively to the Chalky Clay with Warley Hill, and of nearly similar height, I have indicated by an asterisk in that figure the place on Billericay Hill which would correspond to this on Warley.

On the line dividing Sheets 1 and 6 the gravel occurs on the summit of Telegraph Hill, Swanscomb, at an elevation of about 400 feet*.

On Hampstead Hill top, near the Spaniards, at an elevation of 440 feet, a very small patch of this gravel remains, and is shown in the Geological Survey Map of Sheet 7. In the north of Sheet 6, at an elevation of 557 feet, gravel occurs on Well Hill, which is on

* The Ordnance records do not contain the elevation of this hill; but, from a surface-mark of 325 feet to the south-west of it, its elevation cannot, I think, be much under 400. I have to thank the Director of the Ordnance Survey for information as to the elevation of some of the places referred to in this memoir.

the northern slope from the chalk escarpment of the Weald; and, according to the Geological Survey memoir, this caps the Lower Tertiary outliers at Headley (in the east centre of Sheet 8), which attain elevations of 618 and 627 feet.

Within the Wealden chalk escarpment, and resting on the Neocomian, there occurs another patch of this gravel on Bowling-green, near Limpsfield. I owe my knowledge of this only to Mr. Topley, of the Geological Survey, who mapped that district, and who informed me that the gravel was made up chiefly of Lower Tertiary pebbles and subangular flints, and that its elevation, he estimated, was between 400 and 500 feet. It is shown in the Geological Survey map, Sheet 6, and lies about 9 miles south-west of Well Hill.

Proceeding westwards, along the northern escarpment of the Weald, we find an extensive sheet of this gravel spread out in North Hants. That portion of it which lies in the north-west corner of Sheet 8 extends up to the edge of the Wealden excavation, for one patch of it overlooks and commands that excavation, lying at an elevation of about 600 feet at Cæsar's Camp, near Aldershot (see figs. II. and III.). South-west from this, and stretching as far as Meadsted in the south-east corner of Sheet 12, this sheet of gravel spreads out at high elevations over the chalk which bounds the Wealden excavation here and forms the parting between the drainage to the Thames and that to the Southampton water. In the railway-cuttings it is of very irregular thickness and full of large subangular flints reaching the size of a bullock's head. From this point to the extensive sheet of gravel in South Hants the chalk country, occupying for the most part lower elevations than those reached by the gravel on either side of it, has been so denuded that the cuttings of the railway which traverses it from Basingstoke, in the N.E. of Sheet 12, to beyond Winchester in the north of Sheet 11, are quite bare of gravel, though the tops of most of them are below 400 feet. On the cuttings of the railway that branches off from Basingstoke to Salisbury, however, at about 400 feet, a few small patches do occur, not far from the junction of the railways.

The South Hants, or New-Forest sheet, is delineated in the map to Mr. Codrington's paper, page 528, of vol. xxvi. of the Quarterly Journal, and it occupies parts of the south-west corner of Sheet 11 and south-east corner of Sheet 15. Only small portions of this gravel formation of South Hants, viz. those of the highest elevations, belong to the stage now under consideration; the rest has (except so far as the lower layers of it may represent the gravel at higher elevations) accumulated during those successive stages of emergence which are described hereafter. Their relative positions appear in fig. V. The highest elevation attained by any portion of this gravel in South Hants appears to be Bramshaw Telegraph Hill, in the east of Sheet 15, which Mr. Codrington gives as 419 feet. Westward from this gravels occur at high elevations towards the south-western extremity of England, patches of gravel, composed of quartz pebble, remaining on downs, even near the Lizard, at elevations of 360 and 400 feet*.

Northwards from Hampshire the gravel of the great submergence is extensively spread over the high grounds of Lower Tertiary and Chalk in the north of Sheet 12 and south of Sheet 13, reaching elevations of about 600 feet. North-east from this it ranges over the Lower Tertiaries and chalk of the north-west part of Sheet 7 and south-east part of 46, gradually, however, falling to somewhat lower elevations as it approaches the edge of the Chalky Clay in the last-mentioned sheet.

Beyond the chalk escarpment, running through Sheets 15, 14, 34, 13, and 46, and outside the limit of the Chalky Clay, the gravel occurs over the Jurassic formations up to elevations of 539 feet, near Oxford (about the centre of the dividing line between Sheets 13 and 45), and to a greater height in the Cotteswold region, occupying the east of Sheet 44. The gravels of this region are described by Mr. Hull as reaching elevations of 700 feet†. Mr. Lucy, in a paper on the gravels of the Severn, Avon, and Evenlode, and their extension over the Cotteswold Hills, read before the Cotteswold Club in 1869, and printed for private distribution, has confirmed this, as has Prof. Phillips also, in his 'Geology of the Thames Valley.' In this paper and another subsequently read before the Cotteswold Club, Mr. Lucy describes the occurrence of flints in these gravels at elevations exceeding 600 feet, and the gravels with quartz and quartzite pebbles up to elevations of 750 feet; but having found pebbles of quartz and quartzite, which are so characteristic of these gravels, occasionally at greater elevations still, he infers that the Cotteswolds must have been entirely submerged. Of this, however, the evidence does not appear to me reliable, so far as it has been made known.

Patches of gravel at great elevations containing the remains of marine mollusca, like those in the Moel-Tryfaen bed, occur on the western edge of the Pennine in Sheet 81, the highest of which appears to be that found by Prof. Prestwich near the Setter Dog Inn, above Macclesfield, the elevation of which is stated to be between 1100 and 1200 feet‡, while that so long known from Mr. Trimmer's discovery at Moel Tryfaen, near the Menai Straits, reaches the elevation of 1350 feet. In describing Stage IV. I shall explain why it now seems to me that the gravel of these great elevations belongs to the present stage, and not, as I had long supposed, to the close of the Glacial period §.

* Budge in Trans. Roy. Geol. Soc. Cornwall, vol. vi. pp. 1 & 91, and Tyack in same, vol. ix., quoted by W. A. E. Ussher in 'The Posttertiary Geology of Cornwall,' printed for private circulation in 1879.

† Hull, in Quart. Journ. Geol. Soc. vol. xi. p. 477.

‡ Darbishire, in Geol. Mag. vol. ii. p. 296. They have also been found by Mr. Close at 1000 and 1200 feet in the east of Ireland, near Dublin (Geol. Mag. decade ii. vol. i. p. 194).

§ This cardinal error (which I appear to have shared with all other geologists who have given attention to the Glacial Drift) misled me into supposing that the submergence of the Weald had accompanied the formation of the gravel marked *f* in fig. VI. (Quart. Journ. Geol. Soc. vol. xxvii. p. 3); for, as

From the Cotteswold region and from Sheet 53 towards Lincolnshire gravel does not occur at such high elevations; for, in the first place, land of such height does not exist in that direction, and in the second the degrading action of the ice of the Chalky Clay has, as far as this ice reached, either destroyed the beds of this stage or its moraine has concealed them; but about the centre of the line dividing Sheets 62 and 54, near to fig. XVII., and just beyond the limit to which this ice appears to have extended, Mr. Crosskey * describes a deep section at Frankley Hill of water-deposited sands and sandy clays, with erratic blocks derived from Wales, at an elevation of 650 feet. At West Haddon I found a small patch at a considerable elevation on one of the shaded spaces representing islands in Sheet 53 of map No. 2 (Pl. XXI.); but most of the gravel in this direction is that described in Stage III., and distinguished in the plate by the letter *c*, or that described in Stage V., and shown under the letter *e*.

On the eastern slope of the Pennine, however, *i.e.* in Sheets 82 and 87, we ought, *primâ facie*, to meet with gravel patches nearly, if not entirely, corresponding in elevation to those on the western slope in Sheet 81; but we do not. This has been a subject of great perplexity to geologists, and theories connected with currents have been offered to account for the case. The level to which gravel rises on the eastern slope of the southern extremity of the Pennine does not appear to be above 350 feet; and drift of all kinds is said to be absent above that level on this slope as far north as the river Aire, in Sheet 92; but north of that river to be present in abundance up to the water-parting itself in Sheet 102, over which the blocks of Shap granite have travelled from the western slope†. This I shall discuss in relation to Stage V., merely observing for the present that the formations of the stage now under consideration appear to me to have been removed from this part of the Eastern Pennine slope by the ice of the Chalky Clay described in Stage III., as they have also over the area at lower elevations coming within the limit of the broken line shown on Map No. 1.

In the easterly direction towards France the gravel occurs at lower elevations than in Sheet 6, the principal remnant of it in that direc-

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it was clear to me that the Weald had been submerged, and its denudation been completed principally by marine, and not by river-agency, there seemed no other alternative than this, if the Chalky Clay had either been synchronous with, or been followed by, the great submergence. The recognition, however, of the fact that the submergence preceded that clay removed this misconception and many others with it. The restoration map, No. II., which accompanies the paper in the Quarterly Journal just referred to above, in which the submergence of the Weald is shown, represents, so far as the part south of the North Downs is concerned, very closely the condition at the maximum of submergence during Stage II., but not that north of the Downs. The other restoration map to that paper (No. III.) is, in view of the sequence of events traced in the present memoir, inapplicable.

* "Report to the Brit. Assoc. of the Committee on Erratic Blocks," Nature, vol. xx. p. 440.

† Dakyns, Quart. Journ. Geol. Soc. vol. xxviii. p. 382.

tion, though probably not representing the height reached by the submergence there, being the rather large patch on the summit of Blean Hill, near Canterbury. Gravel also occurs on the chalk plateau of Picardy up to elevations of 130 feet or thereabouts *, thus showing the easterly fall of the line of submergence.

From France northwards, through Belgium, the shore of the Glacial sea seems to be very clearly marked by the Campinian sand, a formation of littoral and partly subaerial (or Dune) origin, which in some places is underlain by beds of rolled shingle, and in others passes down into the beds of a foreshore †. This formation, by its structure, seems to represent the gradual recession of the sea as the land rose, and so to coincide with the gravel *c* and *e* described in this memoir.

From the more eastern part of Belgium the beds of rolled flints shown in Dumont's map, and also described by Belgian, Dutch, and French geologists, as inferior to the Campinian, appear, so far as they can be shown to be marine ‡, to indicate the shore of the same sea in this direction; and there can be little or no doubt that the extensive formation of sand and erratics covering parts of Holland and North Germany, to which these geologists give the term Diluvian, is an accumulation of the same sea as that which I have traced as spreading over England after the termination of the Red Crag, and into which also the flood-waters of the Rhine escaped during the Glacial summers which gave rise, as they flooded the land near the mouth of this river, to the Limon Hesbayen.

Pebbles of quartz and quartzite are abundant in the gravel which caps the contorted Drift on the Cromer Cliff §, as are also in some places the corroded fragments of marine shells. In varying proportions these pebbles occur in all the gravels which I have described at high levels. They have been carried down successively in the Weald as the emergence and denudation of that region proceeded, and are found there in gravels ‖ several hundred feet below the elevation up to which the gravels that I have been tracing show the Weald to have been submerged. In the eastern part of the area over which I have described these gravels as occurring at high elevations the flints are in excess of the pebbles of quartz and quartzite, but in the western these proportions are reversed. The principal source from which these quartz and quartzite pebbles have come seems to have been the Triassic conglomerate which ranges through Sheets 62, 63, 71, 82, and thence northwards, and against which

* Barrois, in Proc. Geol. Assoc. for 1879, p. 31.

† Vandenbroeck and Cogels, 'Ann. Soc. Malacologique de Belge,' vols. xii. and xiv.

‡ The Dutch and Belgian geologists are not altogether agreed to what extent these "Cailloux roulés" are marine or not. Anyhow the depression traced in the present stage carried the sea of the Campinian over a portion of them.

§ These gravels, though marked *c* in fig. VIII., because they originated at the commencement of the emergence, and continued as a series during the formation of the Chalky Clay, are no doubt partially coeval with the gravel of the culmination of submergence, which is shown in the other figures as *b'*.

‖ Topley and Forster, Quart. Journ. Geol. Soc. vol. xxi. p. 452.

the western edge of the ice, towards the last part, at least, of its retreat during the present stage, and throughout its advance during Stage III., rested. Hence their great profusion on that side. In the case of the gravels accumulated during the advance of the ice and emergence of the land in Stage III., there is a more intimate connexion as regards constituent material between them and the morainic clay, these gravels, where they approach this clay, being composed, in a most marked way, of the harder materials of which it is made up, so that they are flinty in the Eastern, and oolitic in the East Midland counties; while in Sheets 1 and 7 pebbles from the beds numbered iv. and viii. in fig. VI. form a considerable proportion of the whole material; and in Sheets 66, 67, and 48, the rolled chalk so characteristic of the Morainic clay is, where the gravel is overlain by this clay, associated in the upper part with the flints and quartzites of the overlying morainic mass, in which position also the sand of *c* is, in Sheet 66, often largely made up of chalk grains *.

Up to the time of the setting in of the general submergence of England, that is to say during the formation of beds *b 1* and *b 2*, the only sea of which we find any indication is that of the Crag, extended northwards so as to reach the Humber; and consequently, as the inclination of England, so far as it differed from what it now is, was more easterly, the ice, which descended from the eastern slope of the Pennine, sought this sea, so that the earliest Glacial accumulation, the Till *b 2*, and the basement clay of Holderness represent the morainic extrusion of this ice on the sands *b 1* of its bottom; and if there be any other glacial accumulations of similar age in England, they can only be of a purely terrestrial nature.

After the completion of the great submergence, however, this was different, and the ice sought the sea in its changed position, travelling to it under the entirely altered inclination of England which had thus taken place, as we shall see in examining the phenomena of the Chalky Clay.

To arrive at an idea of what this inclination was, we must compare the evidences of the submergence in the different parts. Cromer-Lighthouse hill, in fig. VIII., is one of the highest points in Norfolk which is covered by marine gravel (for shell fragments occur in this gravel capping the Contorted Drift in the Cromer Cliff), and its height is 247 feet. The distance from this to Moel Tryfaen, where the gravel with marine Mollusca lies at the elevation of 1350 feet, being 230 miles, and the difference in altitude 1103 feet, it would, if the entire submergence were shown at Cromer, as it is at Moel Tryfaen, give the westerly increment of depression as nearly 4·8 feet per mile; while the distance to Well Hill (where, from the summit of the chalk downs not having been covered, we get the limit of submergence at about 560 feet) being 120 miles, it

* At Bealings, in the north of Sheet 48, this presence of chalk in abundance continues in the upper part of the gravel, though uncovered by the clay, for a mile or so only beyond the limit reached by the clay, the chalk disappearing from the gravel beyond this distance.

would give a southerly increment, on the eastern side of England, of 2·6 feet per mile. As, however, there was an unknown depth of water over Cromer Hill, we must compare the elevation of the gravel where it stands against contiguous unsubmerged summits, as it does at Well Hill, on the flanks of the Chiltern and Marlborough hills, and on the eastern slope of the Cotteswolds, with its elevation at Moel Tryfaen. Owing to the uniformity of the level along the north Downs, through Sheets 8 and 12, this increment from Well Hill comes out at a little more than 3·5 feet only; but from the Chiltern and Marlborough hills it is a little over 4·4 feet; and if we take the limit (750 feet) above which no actual beds of gravel occur on the Cotteswolds, as the limit of submergence in that part, it gives the same figure. A mean of these figures gives very nearly 4 feet per mile for the westerly increment; and if we reckon at that rate of decrease eastwards from Moel Tryfaen to Cromer, it would show a submergence at the latter place of 430 feet; but this, from the evidences traced in stage V. of the amount of the rise during the Chalky Clay, is, I think, more than was the case. From those evidences, the depression at Cromer would appear to have been little more than 300 feet, which would allow upwards of 150 feet depth of water above the general surface of the Contorted Drift, *i. e.* the parts where this has not been forced up by the contorting agency; and this would be sufficient for such false bergs as I have supposed, from Nordenskiöld's description, those must have been which carried the marl masses, to float and ground in. Probably, therefore, 4·5 feet per mile is as near to the truth as we can get for the westerly increment. If we take 300 as the limit at Cromer, and compare it with Well Hill, which is distant from Cromer 120 miles, it gives the southerly increment of depression as a little under 2·2 feet per mile. On the western side of England the increment of submergence, instead of being from north to south, as it is in the east, is the reverse; and the distance from Bramshaw, in fig V., to Macclesfield being 160 miles, there is a northerly increment along this line of between 4 and 5 feet per mile; and with this the position of *b'* on the Cotteswolds at 750 feet agrees. I shall collate these calculations with those derived from the evidence afforded by the elevation of the junction-line of the gravel *c* with the Chalky Clay over it in Stage III., and of the gravel *e* over the Chalky Clay in Stage V.

Stage III. *The Middle Glacial Sand and Gravel and the Chalky Clay.*

Fig. II. (Pl. XXI.) is a reduction on nearly the true scale of that at page 376 of vol. iv. of the Memoirs of the Geological Survey, and exhibits the position of the gravel of North Hants described in Stage II. relatively to the Wealden excavation; and in order to show the extension of the gravel northwards from the patch at Cæsar's Camp in this figure, I have added fig. III., constructed by myself, in which, unavoidably, the vertical scale is considerably in excess of the horizontal.

The ridge of chalk shown in these sections is a low part of that rectilinear ridge which, running due east and west, is called, as it rises to greater elevations, the Hogsback, and forms a portion of the escarpment of the Weald.

Fig. IV., on the true scale, is reduced from a portion of one of the sections given in the Geological Survey Memoir of the Isle of Wight, and shows the position of the South-Hants gravel relatively to the rectilinear chalk ridge which runs through that island and is continued through the Isle of Purbeck. This ridge and that of the Hogsback appear to me, along with Portsdown Hill, to be of distinct origin from the general curvilinear escarpment and foldings of the Chalk through England, which resulted from disturbances at an earlier part of the Tertiary period, and to be due to the movements which accompanied the recovery from the great submergence which I am about to trace. The denudation which accompanied these upthrusts of the chalk, both in North and South Hants, has, it seems to me, removed much of the Lower Tertiary which, covered by *b 2*, had previously extended with an easier slope over the Chalk as the earlier Tertiary movements and denudation had left it. In one or two places gravel rests on the upturned chalk; and this seems to me to be a remnant of that which accumulated during the rise which commenced with this disturbance and denudation. In order to show the connexion of the isolated bed of gravel on Headon Hill in this section with the rest of the South Hampshire sheet, I have added another by myself (fig. V.), in which the vertical scale is also unavoidably in excess *.

Under the influence of an elevatory movement in general over England, the local convulsions attending which have thus left their record, the sea-bottom over which the gravel of the great submergence had been spread began to rise. As it did so, the action of the waves removed much (most, indeed) of the gravel, leaving it only in patches of greater or less extent in spots that, from some particular cause or other, were protected from this action, until by their emergence they became entirely free from it. Over the rest of the bottom this action not only removed the gravel, but denuded the older beds also, so as to produce (or probably, over the formations older than the Pliocene, in most cases only to deepen) the troughs, valleys, or depressions which separate these remnants of the gravel at highest elevations from each other. In these denuded spaces gravel again accumulated during pauses in the movement of elevation, which was subjected to the same action in its turn as the gravel before it had been. Where the slope is easy, however, there may have been in some cases no denudation, and the gravel at lower elevations may be that which covered the bottom from the time of greatest submergence onwards till emergence, such as that marked *c* and *e* in fig. V. If so, the gravel *e* in that figure would represent *c* and *b'* also.

* I have availed myself of the map to Mr. Codrington's paper in Quart. Journ. Geol. Soc. vol. xxvi. p. 528, and the Geological Survey Sheet, in constructing this section.

Over the region of formations older than the Pliocene the extent to which this denudation has occurred is in most cases not to be gauged, by reason that so much denudation had preceded this which we are now considering; but in Sheets 68, 67, 66, and parts of 48 and 50, or in those parts at least of them where the Chalky Clay in great thickness has not masked the preceding formations, we can perceive the way in which this denudation has acted upon the formations accumulated during stages I. and II. It was in this way, therefore, that, as the sea-bottom rose, the Contorted Drift became so much denuded and separated into detached portions, such as those shown in fig. I., the spaces or troughs between these detachments giving rise to the East-Anglian valleys *,—valleys which, although thus originating, were, as I shall show in the sequel, further modified by glaciers from the land-ice of the Chalky Clay.

The spaces thus excavated in and through the Contorted Drift have been to a great extent occupied with the gravel *c*, so that the beds of Stage II. protrude in bosses through it.

The progress of this rise during the accumulation of the Chalky Clay is shown by the position of that clay (*d*) relatively to the gravel of greatest submergence (*b'*), and other formations of Stage II., in the accompanying figures and Map 1 †.

Fig. VI. shows this along the southern edge of that clay, fig. VII. along the eastern ‡, and fig. VIII. along the north-eastern—the highest part of the gravel marked *c* in this last figure being, as before explained, *partially* coeval with that marked *b 2* in the other two figures, as well as in figs. II., III., IV., and V. The amount of emergence which had taken place when the ice to which this Chalky Clay was due decayed, I shall examine in the sequel; but from the clay spreading up against the flanks of the islands, shown in figs. VI. and VIII., some way above the sea-level of the time, the *amount of this rise* is not indicated by the upper limit of the Chalky Clay in these figures.

* See Harmer and myself in Quart. Journ. Geol. Soc. vol. xxxiii. p. 74.

† The delineation of the Chalky Clay in this map is, with the exception of Sheet 7, from my own work and that of Mr. F. W. Harmer in Norfolk; save that in the east of Sheet 46, south-west of 70, and south-east of 71, I have been favoured with more accurate delineation from Geological-Survey sources, through Mr. Whitaker. Sheet 7 is from the Survey map, and is the only sheet of it that I have seen in which the Glacial beds are given. In the north-west of Sheet 66 some of the clay is concealed, or its place is taken by the gravel *e'*; but as this gravel has resulted from the washing-out of the clay, as described in Stage IV., and it cannot be seen how far the clay may have been thus removed, and both are so mixed up in alternate patches that, on the very small scale of the map, they would be difficult of separation, the whole is shown as the clay.

‡ In this figure VII. the bending of the shading representing the London Clay was intended to show the *folding* of the older strata within this hill; but from a section on the true scale furnished me by Mr. Dalton, of the Geological Survey, under whose observation the late well-borings through to this hill have come, the fold is much greater than I have here shown it, and so much so as to bring beds III. and IV. above the datum line in the centre of this figure. It is, in fact, exactly that fold which, in the Phil. Mag. for 1864, I showed, hypothetically, should occur at each successive concentric arc of the series of which this hill formed a part.

In Stage II. I have shown that the great submergence extended from East Norfolk in an increasing degree southwards, and with still greater increase westwards; and at the conclusion of the description of that stage I have attempted to arrive at the amount per mile of this increment. Now the line of gravelly sea-bottom in the respective regions at the time when the Chalky Clay was deposited over it, outside the broken line in the map, is shown by the elevation at which the junction of that clay with the gravel *c* takes place; and this will be found substantially to agree with the increment of submergence traced in Stage II., so far as intervening irregularities in this bottom do not interfere with the case, this junction being illustrated by figs. X. to XIII.

Beginning with fig. XIII. at about 40 feet above Ordnance datum, on the North-Suffolk coast in Sheet 67, this junction rises to about 80 or 90 feet in the centre of Sheet 66 (see fig. IX.). From Sheet 67, south-westwards to the north-east of Sheet 1, it rises to 100 feet in the north-west of Sheet 48, to about 170 in the north-east of Sheet 1 (see Margaretting cutting in fig. VI.), and about 300 in the south-east of Sheet 7. The westerly rise of this line is greater, in accordance with the increment of submergence, in that direction, which is traced in Stage II.; for from 100 in the north-east of Sheet 48 it rises to between 260 and 300 in the south-east corner of Sheet 46 (whence fig. XI. is taken), and thence to about 380 in the north centre of Sheet 53, and if I am right in my interpretation of Messrs. Crosskey and Woodward's section (fig. XVII.), to 460 in Sheet 62. Irregularities in the depth at which the sea-bottom, represented by this junction of the gravel *c* with the clay, lay below the sea-surface interfere locally with the uniformity of this rise of the line; as, for instance, this junction at the north end of sect. VI. is at about 150 feet, and in the north of the Roding Channel further west, and so round to the north-west side of the small island divided by it from island 3 at very little more, whereas in the south-east of sheet 7, at Finchley, it is from 280 to 300 feet *, which is a greater difference than the westerly increment would cause. The height of the gravel *e* above *c*, in fig. XVII., shows that the bottom there also was at one place about 80 feet below the sea-surface. The north-east of Sheet 46 also would seem originally to have been a deep place if the gravel at Arlsey and Biggleswade be that marked *c*; but I think such is not the case, for I failed to find any section showing it under *d*.

If we take the position of the clay *d* representing the moraine as indicative of that of the ice †, we can see that with the depres-

* From the delineation of the gravel in Sheet 7 of the Geological Survey Map, *d* would appear to be underlain by *c* all round Finchley; but I found the Chalky Clay resting in places on the London Clay when the cuttings of the Edgeware Railway were in progress. Most of the gravel also shown as "pebble" is the older part of *c*, being that called by Prof. Hughes, in vol. xxiv. of the Journal, the "gravel of the higher plain," which had to a great degree emerged before the ice reached it.

† The view to which the earlier study of the subject led me was, that the Chalky Clay represented moraine extruded under the sea, or left there as the

sion thus increasing southwards and westwards on the eastern, and northwards and westwards on the western side of England, the ice *at the close of* the Chalky Clay entered the sea, which at this time covered the Thames and Severn systems, and was still sufficiently deep to submerge some of the water-partings between the Thames and Severn, and that also between the Severn and the Welland, in the following way. It entered the sea over the Thames system by the valleys of the Roding and Lea in Sheet 1, by that of the Colne in Sheet 7, and over the water-parting, probably then emerged, between the Ouse and Thames systems in Sheet 46, overwhelming, as it did so, a small island represented by Stewkley and the country a short distance around that village, and another represented by Whaddon Chase; while in Sheet 53 it entered the Severn system by the valley of the *Warwickshire* Avon, which is a branch of the Severn. The extent to which the water-partings had at this time emerged I shall examine in Stage V.

Thus we find the partially emerged condition of England at the close of the Chalky Clay; and it is easy to carry back from it our ideas to that more submerged condition when the laying down of this clay commenced, and when ice, which had been in existence during the formation of the Lower Glacial beds *b 2* and *b 3* (and, as shown in describing Stage I., even during the Crag, though it may not have reached the sea), after retreating in consequence, even in the east, partly of increasing submergence, but mainly from the changing inclination of the land, to the higher slopes of the Wold, began to advance.

The cause of that advance, so far as it did not take place in the new direction from change of inclination only, seems to receive its obvious explanation in the elevation of the land from the great submergence of Stage II., which by gradually exposing a loftier and more extensive area of the mountain region of the north of England for the interception of the Atlantic vapour, caused an augmentation of the ice in taking that new direction which was the consequence of the changing inclination of England; and it was in this new direction that the ice to which the Chalky Clay was due advanced. Seeking the sea, the ice which descended the eastern slope of the Pennine found, as it crept round the lower flank of the southern extremity of that elevated region, this sea over the centre of England, both nearer and in greater depth than in its old direction of Norfolk and Suffolk, while parts of its former bed in Norfolk emerged, as shown in map 2 and figs. VIII. and IX.

Sand and gravel (*c*) accumulated under the sea in the channels formed by the ancient valleys in older formations, and those

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ice receded by increasing submergence; so that when by this it had retreated from the Chalk Wold, the Purple Clay was extruded at the time of greatest depression. This view necessarily became changed when I perceived that the submergence preceded both these clays, and that they were accumulated during emergence. The process which I had thus attributed to the formation of the Chalky Clay applies to that of the Cromer Till and the Basement Clay of Holderness.

produced from denudation of the beds of Stage II. by the sea as the land rose, such as are seen in fig. I.; and as by emergence this gravel reached the surface, it was in many parts destroyed by the waves while still accumulating in the parts submerged; but where it was overspread by the moraine of the ice as this advanced upon it, while still beneath the sea, in the way presently to be described, it was more generally preserved, though afterwards to a certain extent destroyed by the thickening or shrinking of the ice.

In places in Sheets 66, 67, 50, and 47, a band of molluscan remains, more or less fragmentary and worn, occurs in this sand and gravel immediately below its junction with the Chalky Clay, as shown by *x* in fig. XIII. The species identified from this band (principally from Hopton, the place whence that figure is taken) are given in the column of the list in my father's first Supplement to the 'Crag Mollusca,' headed "Middle Glacial." These remains present much the same aspect as those from the newer part of the Red Crag; but there are some of which no trace has been found in the Crag, such as *Tellina balthica* and *Venus fluctuosa*, both of which occur in the Bridlington bed, and another, unknown elsewhere, to which my father gave the name of *Trophon mediglacialis*, all of which are not uncommon in this band. There are others, such as *Venus fasciata* (which is unique in the Crag), that occur in this band in great profusion; and this is one of the two species found in Sheet 47, the other being *Astarte compressa*, also occurring in Sheet 67 in great profusion and in a more perfect state than any other species than floaters, but which is also common in the fluvio-marine Crag and in the sand *b 1*. There are also other very small and tender species not known from the Red Crag, but which are Coralline-Crag shells, and have occurred in the Chillesford bed and fluvio-marine Crag, and whose absence from the Red may be attributed to the unfavourable conditions of that formation for their preservation. In the "Introduction" above mentioned Mr. Harmer and I gave our reasons, based on the character of the species themselves, for regarding these remains in Sheet 67 as not having been derived from the destruction of beds of Red or fluvio-marine Crag age, or from the Chillesford bed; but at the same time we pointed out that the remains had an origin which was distant from the place of their occurrence, and had, most of them, been greatly worn during their transport to it by currents along the bottom, the larger shells being for the most part fragmentary, but the smaller species and fry of the larger being often preserved entire, though worn, while with these were an abundance of the valves of *Balanus*, quite unworn, and of the papyraceous valves of *Anomia ephippium* in a perfect state, but which the least wear would destroy. The presence of these we attributed to their having been adherent to floating bodies, such as seaweed, and carried, thus adherent, floating in the currents which moved the sand with the shells and shell fragments over the bottom, to subside as they became detached; all of which I still believe to be correct inferences.

Now, if we bear in mind that during Stage II. the submergence of the region to the north and west of the Crag estuary, which had been land during the accumulation of the Crag beds, took place, and that the sea-bed thus formed lay directly in the new path which the ice took in consequence of the change of inclination, viz. along the west of the Wold and towards Sheet 67, in which these remains for the most part occur, it is easy to see that such remains are those of Mollusca which lived during Stage II., and during so much of the present stage as elapsed previous to their removal; and may not therefore be altogether synchronous with each other, though all of Glacial age, being the remains accumulated on the sea-bottom in some locality favourable for their existence during this time, which the ice in its advance ploughed out and sent on their travels. Thus it is that this shelly band, like the débris of the clay itself, occurs only within some three or four feet of the junction of the sand and gravel *c* with the Chalky Clay. It is generally also immediately beneath or associated with a vein of chalky gravel.

We now come to the question as to how the Chalky Clay, assuming it, as I do, to be the moraine of the land-ice, was deposited or accumulated over this sand and gravel.

Within the broken line shown on Map 1 (Pl. XXI.), the clay, as a rule, rests on the Mesozoic formations, without the intervention of a bed of sand or gravel, though sporadic occurrences of such a bed are to be found; but I have never met with any instance there where this affords an example of the junction of the gravel or sand with the clay of the kind shown in figs. X. to XIII. On the other hand, the rare instances with which I have met present features resembling the jagged termination of the clay in fig. XVIII., where sand has been forced up into the clay. One striking instance of this kind I found displayed at the base of Graffham-Wood cutting, five miles W.S.W. of Huntingdon, in Sheet 52, when the railway from Huntingdon to Thrapston was in progress of construction, where, besides the surface of the sand being jagged into the clay, a portion had been detached and imbedded in the clay. Over this area also the Mesozoic floor on which the clay rests, where it consists of rock, is frequently disturbed, grooved, or twisted. Where the clay rests on the Chalk, that material is sometimes so altered as to form a greasy water-holding marl, and often to graduate almost into the chalkiest form of the clay itself. This greasy chalk prevails near the Great Eastern Railway about Harling station, where the Map is shown as uncovered by the clay, in the south-west corner of Sheet 66. In other parts within the broken line the chalk is disturbed, and the lines of flint dragged up and displaced to a great depth, as in the case of a chalk-quarry at Litcham, described by me in the 'Quarterly Journal' for 1866, p. 84*. This is immediately west of that line in the N.W. of Sheet 66.

* In this paper I erroneously attributed the ice-action, thus dragging up the chalk, to the Lower Glacial period. The bed of chalky loam which I there showed as underlying the Chalky Clay may, perhaps, not do so, but be, as the gravel shown there under the letter *d* is, a bed due to the ice melting.

Outside the broken line the formation is usually underlain by the sand and gravel *c* in those parts of its area which are shown as sea in Map 2; except that towards the close of the formation, in consequence of a change in the mode in which the ice acted, which I shall describe in the sequel, the ice has, in the same way in which it has done in the valley-bottoms through which at the close of the formation it issued to the sea, destroyed the gravel and such beds of Stage II. as there may have been there, and left its moraine resting directly upon the older Tertiary and Mesozoic strata. The way in which the clay sweeps down over the edges of successive Pliocene beds through which these valleys have been cut, and on to the older formation which constitutes the valley-bottom, I shall more fully describe in the sequel.

The clay is thickest where not underlain by any Pliocene formation, that is to say where it has been heaped up on or against some of those islands shown in Map 2, which were overwhelmed or enveloped by the ice, as, for example, near the centre of the division between Sheets 51 and 47, where the railway excavations and well at Horseheath showed it to be 120 feet thick; in the south-east of 52, where it has been banked up against the Neocomian sand-hill of Potton, and where the well at Longstow railway-station traversed 160 feet of it. In the centre of the same sheet also, over the islands lying between the Ouse and the Nen, I heard of wells having been sunk through an equally deep mass of it; and it lies deep against the Wold in Sheet 83. Its thickness where it overlies Pliocene formations, on the contrary, seldom reaches 50 feet, and is more frequently under 20.

The contact or junction of the formation thus described with the gravel *c* beneath it varies in character, and I have selected the cases represented in figures X. to XIV. for its illustration.

In fig. X. the sand and gravel is not quite abruptly succeeded by the clay, but passes into it by a few inches of material which is an intermixture of both. In fig. XI., after the deposition of a small thickness of the clay, the formation of the sand and gravel has been resumed, and the clay thus become interstratified in the sand and gravel. The process appears to have been tranquil and uninterrupted beyond the brief resumption of gravel deposit. Fig. XII. shows similar features in these respects, but varying in the interstratified band of the clay being thicker and in its slightly bending down into the sand and gravel. The lower bed of the clay in this section was much more chalky than the upper, which would show that in the interval between the deposition of the first portion and the next, and during which the intermediate band of *c* was accumulated, the character of the moraine reaching the spot had somewhat changed so far as regarded the proportion of chalk in it. The band of *c* thus intervening here was loamy*.

There can, I think, be no question that these instances show that by some means the moraine of which the clay is composed was in-

* I am not sure that the clay of this figure may not be the Till, and the sand beneath *b 1* instead of *c*, but I think not.

troduced tranquilly over a sea-bottom in which sand and gravel had up to this time been accumulating; and the question therefore arises in what way this took place. In the Geol. Mag. for August 1872, p. 364, Prof. Nordenskiöld gives illustrations of the various modes in which the Greenland and Spitzbergen ice passes to the sea. In fig. 6 of *his* illustrations he shows it in no great thickness, presenting a low and shelving face to the sea, and preceded by a mud-bank sloping also to the sea and identical in shape with the mass marked *d* in the figure (XVII.), which I have copied from Messrs. Crosskey and Woodward's notice of sections in the neighbourhood of Birmingham, presently described. This mode Nordenskiöld describes as having given place in one instance, within the space of two years, to the cutting-out mode of entry, which he shows by *his* figure 5.

This advancing mud-bank appears to me to have been the method by which the morainic material constituting the Chalky Clay was laid so tranquilly on the gravel of the bottom of the sea over which the ice was creeping, while it also overwhelmed the islands with which that sea was studded; and that in this way a cushion was formed for the ice, which protected the gravel from destruction by it; until by the great thickening of the ice nearer its source (*i. e.* within the broken line of Map no. 1), it crushed out both the protecting cushion and the gravel also, forcing it all onward as new moraine, which it in some parts piled up against and upon the islands which it had overwhelmed, and in others left *in situ*; or until, from the mode in which it issued to sea having changed to the cutting-out one shown by Nordenskiöld's figure 5, the gravel and the moraine at first laid over it were near those issues cut out by the ice to be replaced by moraine accumulating in places beneath it. Where the broken line crosses the north-west corner of Sheet 50 this process is distinctly apparent; for here, at Knattishall, *d* resting on *c* presents the same condition of stiff heavy clay which is universal outside this line; but immediately west of Knattishall it changes abruptly, and resting on the chalk without any of *c* under it, *d* presents, over the part where it extends for several miles to the west of this village, the condition of a light-coloured gritty moraine, which some of the pits show to include streaks and masses of this stiff heavy dark-coloured usual form of the clay twisted up in it. It is evident that all this moraine has been formed from the destruction of *c* and of *d* in the original form in which it was deposited over *c*, as well as probably from the destruction of *b 3*, with the addition of chalk from the floor on which these rested. This general crushing-out has given rise to the features within the broken line of Map 1, and the cutting-out I shall describe as prevailing over the parts where the ice at the close of the formation issued to the sea; for the change from the mud-bank mode of entry into the sea to this cutting-out mode seems to have occurred at one particular time over the eastern area of the formation; so that the clay with gravel under it, which occupies most of that part of the area outside the broken line which appears as sea in Map 2, has the gravel generally cut out of the valley-bottoms, and is fringed at its outer edge with spaces in which the gravel has been more extensively cut out—such, for instance, as part of the valleys covered by the clay in fig. VI., which at the northern extremity of the line of this figure have the gravel under the clay, but which, as the ice advanced over island No. 3, have had the gravel entirely ploughed out of them, so that *d* rests directly upon the Eocene. Exactly the same thing is shown by the channel represented by the valley of the Roding which separates island No. 3 from the next island westward; for at the northern end of this channel, close to the dividing line between Sheets 1 and 47, the gravel in full thickness (as in fig. VI.) underlies the clay, but thence to the southernmost edge of the Chalky Clay the whole gravel (except patches of crushed pebbles at the Theydons, at Stapleford Tawney, and at Willingdale) has been wholly ploughed out. In the channel between this island again and the next west of it, which was constituted by the valley of the Lower Lea, the same cutting-out has occurred—the gravel underlying the clay in the north of this channel (where it enters Sheets 47 and 48), but being absent at the southern end, except high up against the edge of the island in the east of Sheet 7, where (at Finchley) it had been covered by moraine before the ice shrank in this cutting-out way into the Lea valley, as I shall presently show it did in the case of all the East-Anglian valleys.

Where the ice overwhelmed the islands the moraine was sometimes forced into their surface, where this consisted of soft material. Fig. XV., taken from an islet of emerged *b3*, shown in Map 2 (on the south of the Waveney, and in the north centre of Sheet 50), is an instance of this.

In fig. X. A I have, on a larger scale, represented the transition from the gravel to the clay where, from being at the present time exposed by slips in the railway-cutting on the east side of Westerfield station, it can be examined minutely.

In this case the upper portion of the sand and gravel *c*, perfectly horizontal and undisturbed, and containing lumps of rolled chalk derived from the moraine, is overspread by a horizontal band of yellowish-white marl (*d'*) from 1 to 1½ inch thick. Upon this band lies one of sand similar to the sand of the sand and gravel *c* below, and of about the same thickness as the marl band; and upon this again comes another band of marl *d'* identical in character and thickness with the first; and on that the amorphous morainic clay *d* rests. This clay here, as it frequently does elsewhere, contains small pockets of gravel, *c'*.

These features appear to me to indicate the following process, viz.:—First, and while the moraine bank was at some distance from the spot, rolled chalk-lumps were carried from it and imbedded in the sand and gravel as this was accumulating. Then, as the moraine approached very near, chalky silt, produced from the attrition of the chalk which makes up so large a proportion of the morainic clay, was carried into the sea by the stream of fresh water which arises from the thawing of the surface of the land-ice and of the snow upon it during summer, and issues beneath that ice; and the sediment from this produced the first or lowest marl band. Winter intervening, this ceased, and for the time the deposit of sand was resumed, giving rise to the thin band of that material which divides the two thin bands of marl from each other. When from the summer meltings the stream of silt poured out again, the upper marl band was laid down; and before this again ceased the moraine itself came upon the spot by a process of slide, the material being, from the water present in it, in the mobile condition of mud.

The commencement of the cutting-out process was (when I drew it in 1864) visible at two points in the long section of the clay resting on *c* given by the North-Suffolk Cliff, in Sheet 67, at Hopton, the clay being in these spots pressed down into the subjacent sand and gravel *c*, which near the junction was in consequence disturbed and squeezed outwards, and the hollow produced by the pressing down was filled with the gravel *e'* resting on the clay. In these instances the process went no further; but where the Waveney valley cuts through the low tableland, of which this North-Suffolk Cliff forms the section, the clay passing through the gravel *c* plunges sharply into that valley down to and under the alluvium, cutting out that gravel in the same way that is shown in the case of the Blackwater valley by fig. VII.

Fig. XIV. represents the same thing, and is taken from the edge of the Blyth valley at Bulchamp, the plunging clay lying like a wall against the sand and gravel; and it was this which, in the earlier days of my investigation, misled me into the idea that the formation was faulted.

In fig. XI. the seam of *d* intercalated in *c* may so appear from the section intersecting the point of the mud-bank as first laid down, followed by a resumption of gravel accumulation before the bank advanced again, or it may be due to the dropping of material dragged from the adjacent mud-banks by floe-ice.

In the north-east of Sheet 45 and south-east of 53, the junction was preceded by the introduction into the gravel of a large number of rounded boulders reaching to the size of a horse's head, just as in Sheet 48 it was preceded by the introduction of rolled chalk. This I found in a large section at Burcott Wood, near Towcester, in Sheet 53.

In the Proceedings of the Birmingham Natural-History Society for 1870, a section at California, near Birmingham (in the south centre of Sheet 62), is given with a detailed description by Messrs. Crosskey and Woodward. This, as it seems to me to show in a striking manner both the mode in which the Chalky Clay came upon the sea-bottom, and the way in which the allowance must be made between sea-bottom and sea-top in tracing the level of the sea at the close of that formation, as I do in Stage V., by the height of the gravel over that clay in the parts where it then entered the sea, I have copied for illustration here as fig. XVII., altering it only to the extent of applying to the several beds the indicative letters which correspond to those used in the other figures of this memoir.

The bed marked *b* in it is described by Messrs. Crosskey and Woodward as a ground moraine containing striated blocks, and was, I infer, moraine formed on land prior to the retreat of the ice as the sea invaded this region during the sinking of the land in Stage II. The clay so marked *d* is not described by these gentlemen as containing chalk; but I feel no doubt that it is the Chalky-Clay formation accumulated beyond the limit to which the chalk débris reached in the moraine, for this débris diminishes greatly through Sheet 63. They, however, say that it contains pockets of gravel and sand, the former being small and water-worn; and this is the case with the Chalky Clay in many places, as, for instance, in that overlying *c* in fig. X., where they are shown by the letter *c'*. It seems to me that at this place the mud-bank entered the sea where this was at first 80 feet deep, but eventually only 60. The sloping face of this bank is that which is overlain by the gravel *e*, while the gravel *c* represents the sea-bottom on to which it slid. As the morainic material slid down this face each summer on to the gravel bottom, it rolled up the gravel deposited thinly on its slope in the interval, incorporating it in pockets in the clay.

In fig. XVI. (which is about 1½ mile south of Guist in fig. VIII.), a band of *c*, about a foot thick, runs through the Chalky Clay at an inclination corresponding with the face of the mud-bank in Nordenskiöld's figure, and with that in fig. XVII. A talus of the clay over the lower end of it prevented my seeing how this band terminated in the clay; but it seems to me to be simply the gravel formed on the sloping face of the mud-bank during a short interval in which no accession was made to it, and which, when accession took place, instead of being rolled up, was covered by the mud. The absence of gravel under the clay, which here rests on the Contorted Drift directly, is thus not due to the moraine being laid down above water; for the elevation of the section is below that at which on either side of the line of fig. VIII. the junction of *c* with *d* occurs, this junction, though for the most part destroyed by the subsequent cutting-out action of the ice along the valley, being still preserved on either side of the line of that figure, viz. in Fakenham town in the one direction and ¾ mile E.S.E. of fig. XVI. in the other.

When, by the retreat of the Chalky-Clay ice, the progress of this bank in fig. XVII. ceased, the sea, instead of the little gravel it deposited in winter being rolled up the next summer into pockets as the mud moved again, deposited without interruption its gravel (*e*) over the sloping face of the bank, now no longer recruited with morainic material. This it did up to the height to which the sea-surface rose, the bank forming its foreshore, no appreciable change in the level having in the interval occurred. Such gravel, therefore, though it overlies the clay *d*, necessarily inosculates with that marked *c*, of which beyond the tail of the bank it was the immediate and uninterrupted continuation. The gravel *e* is described by Messrs. Crosskey and Woodward as more clayey than *c*; and this, I infer, was in consequence of the wash of the waves against the upper edge of the bank of *d*, where this bank, after the ice had disappeared, was left as the foreshore.

According to Messrs. Crosskey and Woodward, the level of the canal here, where the junction of *c* with *d* occurs, is 460 feet above Ordnance datum. This was the sea-bottom; but the level of the sea-top is indicated by the gravel *e*, and this was as much higher than the bottom as that gravel resting on *d* is above the place where it rests on *c* beyond the tail of the bank, which is about 10 fathoms.

It is evident that where, or when, moraine is beneath the glacier, *the ice* cannot degrade. If degradation then takes place it must be effected by the motion, not of the ice, but of the moraine itself; and we see an instance of this in fig. XX., where, during the shrinkage of the ice into the Gipping valley, as shown in fig. I A, this moraine has ploughed out the sand; but as we find large spaces within the central limits of the Chalky-Clay formation uncovered, or nearly so, by the moraine—such as those in Sheets 69, 64, 65, and 51—it is evident that it has been stripped from this part as the ice advanced, to contribute to the material of the moraine which has been accumulated nearer to the outer edge of the ice.

It is only on the assumption that the moraine, after its first deposition, formed a protecting cushion to the subjacent rock, that I can find an explanation of the character of the clay in Sheet 1; for the clay here contains only the hard chalk of Yorkshire and Lincolnshire, or of those layers near the base of that formation which crop out in the west of Sheets 46 and 51. Now, unless the soft chalk of Sheet 47 had been first covered by a cushion of moraine, and thus protected from degradation, could the material from it have escaped forming a part, and that, indeed, much the greater part, of the chalk contained in the clay in Sheet 1? The case is similar with Sheets 47, 48, and 50.

It is in this way, then, only that the ice could, it seems to me, have passed over those parts where newer Pliocene beds, antecedent to the Chalky Clay, remain undestroyed; for even in the valleys there this destruction has occurred from the thickening of the ice, as I shall show presently. Much of the ice, therefore, outside the broken line seems to have had no great thickness.

Where this antecedent cushion of moraine has been cut through by the ice, the floor of older formations is disturbed; and where this is hard it is sometimes grooved, and over this disturbed floor later moraine has been brought. This feature is very conspicuous in the bottoms of the Norfolk valleys, where they are not concealed by gravel and alluvium; but these more recent deposits have filled up those valleys to so considerable an extent since the ice passed down them as to conceal to a great degree the phenomena produced by the Chalky-Clay ice at the period of its greatest extension.

In Map 2 (Pl. XXI.) those parts which rise well above the level of the junction of the clay with the sand and gravel *c* beneath it, *in their immediate neighbourhood*, are in shade, and so appear as islands around which this sand and gravel accumulated, as appears also from figs. VI., VII., and IX. A comparison of this with Map 1 in the field will show that this delineation is thus founded on actual evidence from the broken line as far as the edge of the clay. Beyond this edge the delineation is based on the continuation of the rise of the sea-bottom represented by this line of junction, according to the increment of submergence traced in Stage II., which very fairly agrees with that of the line of this junction as far as it extends, and with that of the line of the gravel over the clay (*e*) which I shall trace in Stage V. Within the broken line, over the part where the junction has been for the most part destroyed, this delineation is continued only in outline, and on the basis of the decrease in the submergence eastwards towards Norfolk. The result shows, in my view, a very close approximation to the geographical conditions when the ice had reached the broken line. So far as the land may have risen during the advance of the ice beyond it, and before the shrinkage into the East-Anglian valleys took place, the representation would not be exactly synchronous in all its parts; but this part of the rise was, I think, too small to make any appreciable difference in the representation. The small islands or islets in Sheets 48, 49, 50, 66, and 67 represent protrusions through the gravel *c* of the beds of Stage II. such as those in fig. I., and they are probably far more numerous and extensive than shown in the map—those shown being only such as, occurring beyond or at the edge of the Chalky Clay, or exposed by breaks in the pall of that clay, can be thus detected. Most probably the tablelands out of which the river-valleys of these Sheets have been excavated are to a great degree formed of similar islands covered up by the Chalky Clay, such as that on the south bank of the Waveney, from the summit of which fig. XV. is taken, and where the moraine which overwhelmed it has been forced or wedged into the surface of *b3*. Where the moraine did not so entirely cover them we see this to have been the case with the Wensum valley, which in the centre of Sheet 66 is thus formed, the long peninsula to the large island numbered 1 in Map 2 constituting the northern, and a small but long island the southern side of that valley near Norwich.

The representation thus given in Map No. 2 may be regarded as that of the case when two thirds or rather more of the total rise, which in Stage V. is traced as having taken place during the formation of the Chalky Clay, had been accomplished.

The condition of Central and South Greenland is, from Rink's map, evidently that of a number of islands overwhelmed by land-ice, the channels between which form the fjords through which this ice issues to the sea; and the cases of England and Greenland would be identical, were it not that only the very narrow fringe of the archipelago which skirts Davis Straits remains uncovered, whereas in England the islands which remained uncovered were more extensive; and, owing to the more rocky character of Greenland, many of the channels there are much deeper than were any of those in England.

On the vegetation of this uncovered fringe the Greenland reindeer feed.

Compared with the condition of England at the period of greatest submergence, this map would present great differences, for in a representation of the state of things at that time every island thus shown in Sheets 1, 2, 48, 49, 50, 66, 67, and 68 would disappear, as well as some of the smaller islands in the other Sheets, while all the rest would be reduced in size.

A comparison of this map with that numbered 1 will show to what extent these islands were overwhelmed by this clay; but it is singular that the western part of that one of these islands through which the division-line of Sheets 51 and 52 runs, and which part is formed of the yielding Neocomian sands of Potton and Sandy, rising to no great height, should, though enveloped on all sides by the ice, not have been overwhelmed by it, the clay (and possibly, therefore, the ice also) not having covered it. This is the case also, though to a less extent, with the island formed of the same sands around Woburn, in Sheet 46.

The labour which my friend Mr. Harmer gave to the work of mapping Sheets 66, 67, 68, and 69, and the care, skill, and minuteness with which he accomplished this task, enable me to trace exactly the course which the ice took after overwhelming the west of island No. 1 and the islands to the south of it.

The long narrow peninsula which juts out south-eastwards is, like all that part of this island which occupies Sheet 68, formed of the beds of Stage II., capped by so much of *c* as had emerged previously to the particular time of this description. Omitting *d* and *e*, the beds forming the northern end of this peninsula were at this time as shown in fig. VIII. At the southern end they were as shown in fig. IX., and without much or any capping just there of previously-emerged *c*. This peninsula was flanked on its southern side by the narrow island of similar formation to which I have already adverted as forming the south side of the Wensum valley, near Norwich, and which also divides the valley of the Wensum from that of the Yare. This island has probably a greater extension north-westwards than is shown, or was one of a chain extending in that direction now concealed by the almost continuous pall of the Chalky Clay there.

Entering upon the Wensum fjord thus formed, the ice laid the Chalky Clay over *c*; for Mr. Harmer and I found it in that position low down in this valley in a temporary excavation in Fakenham town, though in that part of the valley, and for some distance also south of the part which is crossed by the line of fig. VIII., the junction has been generally destroyed by the subsequent cutting-out action of the ice. That part of island No. 1 which lies in Sheet 66 was not (owing to reasons given in Stage V.) overwhelmed by the ice, which only rose against its southern flank, where it laid its moraine (*d*) in the way shown by fig. VIII. Passing thus south-eastwards, it laid its moraine over *c*, which had been and still was accumulating in the fjord represented by this valley, then partially excavated by marine action out of the beds of Stage II., and also over the south flank of island No. 1, some way above the sea-line, which is represented by the junction of *c* with *d*. This it did as far as the south-eastern extremity of the peninsula, which juts out south-eastwards nearly to Sheet 67, where, on the western side of this peninsula, *d* for a wide space rests on *c*, but above the line of the junction on *b 3*, just as it does against the corresponding slope of the main part of the island in fig. VIII. The eastern slope of this peninsula, as well as the unshaded part beyond it (which represents the valleys of the Bure and Ant), are free from *d*; and the ice did not reach this part, save that where a very narrow neck to the peninsula is shown the ice seems to have for a brief time overtopped it, as minute patches of the clay occur at the heads of valleys there which are tributary to that of the Yare. Constrained thus by this peninsula, it, so soon as it reached its south-eastern extremity, expanded north-eastwards over the shallow sea there so as to reach the north of Sheet 67, covering the sea-bottom formed of *c* in this Sheet, as well as the islets of *b 3* which were interspersed in it; and thus the coast-section in this Sheet is merely that which, omitting the later beds, is presented by the coast-section in Sheet 68 from Bacton south-eastwards *plus* the moraine of Chalky Clay spread over it.

Fig. IX. shows the way in which, after *d* had thus been laid upon *c* in the fjord, the shrinking of the ice, presently to be explained, destroyed, along the Wensum and Yare valley, this first result of the ice-action, and brought about those features which this valley now presents.

It should be borne in mind that the elevation of the line of junction of *d* with *c* along this valley and elsewhere falls eastwards in accordance with the original decrease of submergence in that direction, and shows the inclination of the land to have been proportionately different, even within Norfolk, to what it now is. To this mainly, but possibly in some slight degree also to the rise of the land during the process, is due the rise in the elevation of the junction line from between 30 and 40 feet in Sheet 67, to 90 feet in the centre of Sheet 66, and to a still higher elevation near the head of the Wensum valley.

Where the moraine entered the sea at the termination of the Chalky Clay it is covered by gravel, as traced in Stage V., which was the resumption in these places of that gravel-deposit which, beyond the limit to which the ice reached, had been going on uninterruptedly throughout its advance in the parts still submerged and not invaded by the ice. This, of course, was only resumed up to the level to which the progress of the emergence had brought the sea-line in the different parts when the ice disappeared. In the case, however, of the gravels of Norfolk and Suffolk which overlie the clay, they have, as I shall attempt to show in tracing Stage IV., resulted from a different agency than the sea, that part of England having at this time nearly all emerged. Prior to the formation of these gravels, however, the ice had shrunk from the position it occupied when thus laying down the Chalky Clay over Norfolk, Suffolk, Essex, and East Middlesex; and, uncovering much of the moraine so laid down, had cut through that part of it which had been deposited in the channels and interspaces of denudation, and, deepening these, thus formed the valleys of these counties, which it occupied to a depth, in the east of Norfolk and North Suffolk, below their present bottoms. As the valley of the Yare about Norwich affords the best evidence of this action, I propose to trace it by evidence more particularly in that part.

In the year 1866 my coadjutor in the task of working out the Pliocene structure of Norfolk, Mr. F. W. Harmer, discovered that clay, similar to that which covered the high grounds through which this valley was cut, rested in the bottom of the valley on glaciated chalk. Hence, to distinguish it from the general outspread of the Chalky Clay over the higher ground, and from the Cromer Till, he called it a "third Boulder-clay;" and this was communicated to the Society*.

Soon after this the progress of the excavations for the sewer-works at Norwich brought to light the circumstance that morainic clay, of the same physical character as that of the high ground, lay in association with sand beneath the gravel and alluvium, and much below the level of the Yare river; and this Mr. Harmer and I communicated to the Society†.

Shortly afterwards, in the formation of the branch railway to Cromer, a cutting was made through the hill forming the northern side of this valley, at Thorpe, near the well-known crag-pit of that place, and also just above one of the two instances of this "third Boulder-clay" to which Mr. Harmer had called attention; and so much of this cutting as had not been sloped, I have represented in fig. XVIII.

It is clear from this and from fig. IX. that, after *d* had been laid in the way I have traced it upon *c*, in the fjord represented by the first excavation of the Wensum-Yare valley out of *b* 3 (and probably *b1* also), it was ploughed off by the action of ice moving along the valley, and a confused mass of sand and brickearth resulting apparently from the forcing upwards of the beds *b 1*, *b 3*, and *c*, to the place where this part of the clay resting upon *c* had previously been, and so in a jagged way into the ploughed-off edge of the clay. A very little way to the west of this section, and on the same slope of the valley-side, was a pit, showing a deep section of the Contorted Drift, much twisted about and forced into *c*; and inasmuch as the Contorted Drift is everywhere near Norwich free both from the marl-masses and from the contortions produced by their introduction which are so abundant in Sheet 68, it is pretty clear that the disturbance of that drift which is shown by this pit-section was due, not to this cause, but to the same passage of the ice down the

* Quart. Journ. Geol. Soc. vol. xxiii. p. 87.

† Quart. Journ. Geol. Soc. vol. xxv. p. 445. I think now that this sand must have been similar in position to that in fig. XX.

Yare valley which has produced the appearance of the beds exhibited by fig. XVIII.

In the valley below both these excavations lies the "third Boulder-clay" (*d*), resting on chalk, which is glaciated and converted into the greasy marl, already spoken of, and which is shown in fig. IX. by the letters iii'. On the opposite side of the river, in the lower part of the southern side of the valley, is the long-known crag-pit of Whitlingham; and there the chalk, with the crag overlying it, is in a similar disturbed state, the lines of flint showing that it has been forced upwards by lateral pressure.

In many places in this valley, and in the tributary valleys of the Wensum and Tese, where the floor is chalk, evidences of the same occupation of the valleys by ice after their first excavation are afforded by the presence of morainic clays, generally resembling that on the high grounds, but sometimes more chalky in character. These mostly rest on glaciated chalk, similarly to that in fig. IX.; but in some cases in the Wensum-valley bottom I have found this underlain by a gritty sandy accumulation, which I regard as moraine produced by the destruction of *b 2* or *b 3* and *c*.

The alluvium sheet in the valley of the Wensum and in that of the Yare and its tributaries west of Bramerton, lying lower than the floor of chalk on which the Pliocene formations repose, the evidences which I have been describing of their former occupation by ice are thus not altogether concealed there. In the valley of the Waveney (in the N. of Sheet 50, S.E. of Sheet 66, and S.W. of Sheet 67), however, this is otherwise, and the entire floor of that valley is, with the exception of some prominences of chalk protruding at Diss, concealed by the alluvium up to and above the base of the Pliocene formations. We are thus deprived of the opportunity of examining whether this valley was subjected to the same action as were those of the Wensum and Yare. As, however, the Chalky Clay at the very source of the Waveney, where it takes its rise at Lophamford, plunges over the valley side and passes under the alluvium, and, as I shall show, the next principal valley to the south of the Waveney, that of the Gipping (near the centre of Sheets 50 and 48), has been subjected to the same kind of action as that of the Wensum and Yare, there can scarcely be a doubt that the valley of the Waveney has also.

This valley forms one continuous trough with that of the Little Ouse river, which flows in the opposite direction to the Waveney, and through the north-west of Sheet 50 into the Great Ouse in Sheet 65; and both rivers take their rise in a marsh at Lopham, where the valley, or trough, is as wide as it is much further down, either in the east or west direction. The late Mr. J. W. Flower always (but in ignorance, I believe, of the facts attending the position of the Chalky Clay) insisted upon this feature being irreconcilable with the theory of the valleys or, rather, the one continuous trough having been excavated by the rivers that take their rise in it at Lopham, and run thence in opposite directions; and so, in my opinion, it is; but the position of the Chalky Clay in this trough, applied to the phenomena disclosed by the Yare valley, clears up, it seems to me, all difficulty, and proves that the Hoxne palæolithic brickearth, so well known to geologists by the description of Prof. Prestwich, is of the age of the Chalky Clay itself, though of the latest part of it.

The sections of Mr. Prestwich* show clearly that this brick-earth could not have accumulated while the Waveney valley was in its present state. It must have been formed either before the valley was excavated through the Chalky Clay or when, after having been formed, it was filled up again. Mr. Prestwich (unaware, I presume, of the position which I have described as occupied by the Chalky Clay in the valley bottoms) adopted the first alternative; and he attributed the patches of gravel, which extend along the upper edges or brows of this valley for several miles in this part, to the deposit of the Waveney when it flowed over the Chalky Clay at this high level, and before it had excavated its valley. To this period and to this condition of things, as I understand his memoir, he refers the Hoxne brickearth, which has been denuded on one side by the formation of the valley of the Goldbrook, a stream flowing into the Waveney hard by.

The lateral valley of the Goldbrook, thus on one side excavated out of the palæolithic brickearth, must no doubt be, if not wholly, at any rate partially, of posterior formation to this brickearth; but such is, I think, clearly not the case with the valley of the Waveney; and the explanation which I offer of it, and which appears to me quite sufficient, is that when the ice of the Chalky Clay, shrinking into these valleys and creeping through them, ploughed-out the long trough in which the Little Ouse and Waveney now run, it filled this up, so that the drainage produced from the thawing during summer of the land-surface (and which surface, the ice having shrunk from it, had become covered with vegetation), not being able to escape into the valley, formed a lagoon there—a "Märjelen See" in fact; and that this drainage, collecting what débris there was scattered over the land-surface and swept by the melting snows, carried it into the lagoon. In this way the implements of man and the remains of land and freshwater organisms described by Mr. Prestwich were introduced into the brickearth.

The connexion of the thin envelope of sandy gravel, which Mr. Prestwich shows as wrapping the denuded surface of this brickearth, I defer for consideration in Stage IV., its connexion being with the melting of the ice in West Norfolk, and with the sand and gravel resulting from this, which are described in reference to that stage.

All the East-Anglian valleys exhibit this plunging behaviour of the clay—that of the Blackwater being illustrated by fig. VII., and that of the Gipping by figs. I. and I. A. Both of these valleys presenting this feature at the point where the laying down of the Chalky Clay upon *c* by the precession of the mud bank became arrested, they furnish important evidence of the change in the mode of ice-action which occurred towards the close of the formation,

* Phil. Trans. 1860, p. 304.

and so continued until the ice disappeared. I have therefore given some examples of the way in which we find the moraine in the Gipping valley.

Fig. XX. (which is about a mile south of the line of Sect. I. A) seems to show very clearly the passage of the moraine down the valley, and the ploughing out of the sand by it.

In fig. XIX. (which is three miles north of this in the same valley, and is given to illustrate Stage IV.) the Chalky Clay, plunging into the valley, as shown in fig. I. A, rests on the same thin bed of dark-coated flints of Lower Eocene age over chalk which is present in fig. XX. The figure is as the Section appeared when I copied it, in the year 1864; but I am informed by Mr. W. Whitaker that the Chalky Clay may now be seen in one place to be *forced under this Eocene bed.*

The thickening of the ice in the valleys and its shrinkage from the position it occupied when, by pushing its mud-bank before it, the moraine was laid over *c*, and the change from that mode of deposit to the cutting-out method, is not confined to East Anglia, but is shown generally along the outer edge of the formation; as, for instance, on the heights on the western side of the Lea valley at Finchley, in the east of Sheet 7, the clay rests on *c*, as it does also on the opposite side, in the extreme north-west corner of Sheet 1, and so eastward through the channel bounding the small island in that part; but from this position it plunges some way down the western side of the Lea valley in Sheet 1, cutting out *c* entirely. The same thing occurs with the valley of the Welland, in the north-west corner of Sheet 52 and south-east of 63, *d* resting upon *c* on the heights, as at Desborough Railway Cutting, but in the valley bottom at Harborough, on the Lias. In the case of the Avon valley, in Sheet 53, it rests on *c* at the elevation of about 380 feet in the Kilsby tunnel, and many surrounding sections on the plateau south of Rugby, mentioned by Mr. Wilson; but in the valley-bottom at Rugby, 100 feet below this, it rests on the Lias*.

It is not, however, merely where thus shrinking into valleys that this change from deposition over gravel to the cutting it out occurred towards the end of the formation; for the same thing appears where the ice advanced against the water-partings between the Ivel and Ouzell in the east of Sheet 46, and the Ouse and Thames systems in that sheet and in the east of 45; and which partings, though shown open in Map 2, had at the close of the formation emerged.

Thus it seems to me that though Nordenskiöld describes the change from the mud-bank to that of the cutting-out mode to be continually occurring in Greenland and Spitzbergen, this change took place in east Suffolk and Norfolk at one particular stage, which was when about 80 feet out of the total rise of the land which occurred during the formation of the Chalky Clay that I shall deduce in describing Stage V. remained to be accomplished; though nearer the ice source, as, *e.g.*, in Sheet 53, this did not occur until the close of the deposit,

* Quart. Journ. Geol. Soc. vol. xxvi. p. 200. Report of Rugby School Nat. Hist. Society for 1873.

the gravel *e* reaching everywhere there to as great an elevation as *c* does. This change seems to me to have been produced in East Anglia, which is the area most remote from the ice source, either by a diminution in the supply, or by the greater increase in the distance of the sea which emergence produced in the shallower area to that which it produced in the deeper; so that where the ice reached the sea furthest from its source, it did so by shrinking into the valleys earlier than it did in the parts nearer.

The interglacial age claimed by Mr. Skertchley for the brickearth near Mildenhall and Brandon, with palæolithic implements and mammalian remains, which occurs in the S.E. corner of Sheet 65 and the N.E. corner of Sheet 51, has not yet been admitted generally by geologists.

This brickearth is underlain by the Chalky Clay with some rough gravel between in places, and in some sections has this clay also over it. It seems to me that this brickearth was formed by the drainage issuing westwards from the inosculating valleys of the Little Ouse and Waveney and from the valley of the Lark, when, though the ice was wasting and had withdrawn from those valleys, a large body of it still remained where this had been throughout in greatest thickness, *i.e.* within the broken line of Map No. 1.

It is to be borne in mind that, according to the inclination of the land at this time, the escape of this drainage was not, as now, either to the North Sea or to the Wash, but south-westwards; and it is reasonable to suppose that after the East-Anglian valleys had been vacated by the ice, and this main mass of it still remained, though (so to speak) in retreat, this retreat might be arrested and changed into a slight advance by some temporary reinforcement from the Pennine. Such a temporary advance bringing the ice against the deposits of this drainage would carry Chalky-Clay moraine over them.

Inasmuch as the arboreal and other organic remains described by Mr. Prestwich as present in the Hoxne bed prove that at the time of its accumulation the stream which supplied the sediment for it drained a surface that was occupied by arboreal vegetation, and supported great Mammalia, it seems to me that at this time the moraine which had thus been uncovered by the shrinkage of the ice into the valleys must have become clothed with such vegetation. This association of arboreal vegetation with inland ice is not in accordance with what obtains now in arctic latitudes; but it may have been otherwise in the comparatively low latitude of England during the Glacial epoch. The observations, however, which I have to make on that point, as well as on the coexistence or not of the great Mammalia (most of which could not have existed without arboreal vegetation to support them) with the land-ice in England, I defer to the second part of this memoir.

Stage IV. *The Gravel resulting from the Ice melting in part of the area which had risen above the sea-level.*

The events of which I propose to trace the evidence during this stage, though gradual and far from cataclysmic, occupied but a short time, geologically speaking. In Stage V. the fall of the line of marine gravel (*e*) over the Chalky Clay is traced from upwards of 500 feet in Sheet 62 to its disappearance at Ordnance datum in Sheet 50, as well as the amount of rise in the land which took place during the formation of that clay, from both of which it results that the whole of Norfolk and North Suffolk, with the exception of the parts at lowest elevation in the west of these counties, had at the close of that formation risen above the sea-level, and that the ice which passed through the Norfolk valleys to the North Sea reached it beyond the present coast of Norfolk.

There is, however, in Central Norfolk a large formation of gravel occupying elevated areas over the Chalky Clay, and distributed in alternate patches with it, which is, with slight exceptions, such as that mentioned (in Stage III.) at Stewkley, peculiar to that county—this clay, except such as falls below the line of the gravel *e*, being everywhere else bare and bald.

The greatest mass of the ice lay within the broken line of Map No. 1, up to which, as I have already described, it destroyed and reconstructed all the earlier part of the moraine laid down over gravel; and we may therefore infer that when it had to a great extent shrunk into the Norfolk and Suffolk valleys, an immense mass of it lay high on Western Norfolk, and overlooked the Wensum valley from the west.

In Greenland the melting of the snow on the surface of the land-ice during summer causes torrents of water to pour through fissures in this ice, which eventually issue beneath its termination into the sea; but this water, from the surface-thawing of the ice in West Norfolk, would pour from it into the Wensum valley, filling that valley above the ice which occupied it, and flooding the surface of the moraine which the shrinkage had laid bare.

It is to the currents of water thus poured from this mass of ice, after the shrinkage began, that I attribute those extensive beds of gravel which have been described by Mr. Harmer and myself under the name of "Cannon-shot," the principal extension of which is in the west of Sheet 66. Here, for the most part, they consist of thick beds of flints rolled into the shape and dimensions of the now obsolete cannon-shot of from 12 to 32 lbs. calibre, and even larger; and we attributed their origin to some local modification of the Chalky Clay formation by powerful currents, for we sometimes found imbedded in the gravels heaps of sand formed almost wholly of chalk-grains.

Another feature of these gravels is, that above the confluence of the Wensum with the Yare, near the centre of Sheet 66, they are confined to the western slope of its valley, and to the plateau on the west of it; but immediately to the east of this confluence three great accumulations of gravel, containing (in the westernmost of them at least) a considerable intermixture of the cannon-shot flints, occur at Mousehold, Poringland, and Strumpshaw, apparently resting at the two latter places on the Chalky Clay. The Mousehold and Strumpshaw accumulations are on the plateau of the north side of the Yare valley, the former extending to within a mile of the northern end of fig. IX.; and the Poringland one is on the southern plateau, two miles from the southern end of fig. IX.

Under the conditions of westerly inclination, already described as existing throughout the Chalky Clay, the part of the Wensum-Yare valley which lies east of this confluence had a different fall from that which it has now; for though the bottom of it has been found at Yarmouth to be 170 feet below the marsh*, this at the time under consideration, when all the county had a more westerly inclination, stood proportionately higher eastwards; and the valley being filled with ice up to, and probably somewhat above, the level at which fig. XVIII. occurs, there would have resulted an expanse near this confluence which, if filled with water above this ice, would have been of considerable and lacustrine extent. North of this confluence, however, the Wensum valley (especially where it crosses from Sheet 68 to Sheet 66) would have much the same fall as at present.

It seems to me that the torrents of water which issued from the edge of the ice that thus rested high within the broken line and overlooked the Wensum valley, pouring into that valley above the ice which occupied it, by their torrential character washed out much of the Chalky Clay here, and rolled the great flints in it into the cannon-shot form described. Eastwards and southwards from the place of the ice in mass here, this gravel gradually loses the cannon-shot character, becoming finer and the great spherical flints fewer. The three large beds of this gravel—Mousehold, Poringland, and Strumpshaw—appear to have accumulated in the expanse just described while the Yare valley still remained filled with ice. Eastward of this the gravel along the Yare valley edges becomes finer, and is seen covering the Chalky Clay thinly on the cliff-top on either side of Lowestoft, where this clay overlies the gravel *c*; and thickly overlying it where this clay, cutting-out that gravel, lies in the valley of the Waveney at Somerleyton brickfield and the railway-cuttings at Mutford. The finest material was carried further and spreads widely over South-western Norfolk and North-west Suffolk, while numerous patches of this gravel in its finer condition occur along the edges of the Waveney valley. These latter Mr. Prestwich identifies with the thin wrapper of gravelly sand which envelops the denuded edges, and covers the whole surface of the palæolithic brick-earth of Hoxne; and in that identification I agree. From Hoxne westwards the same bed, increasing in thickness, and often becoming a thick deposit of only sand, stretches northwards into inosculation with the cannon-shot form of the deposit in the north-west of

* Prestwich in Quart. Journ. Geol. Soc. vol. xvi. p. 449.

Sheet 66; while in the same thin form in which it wraps the Hoxne brickearth it stretches westwards to Brandon and Mildenhall, where, according to a section prepared by Mr. Skertchley which was sent to me, it wraps the palæolithic brickearth and the Chalky Clay with which that brickearth is overlain; and in the north-east of Sheet 51 and south-east of 65, and some way over the division-line into the corresponding parts of 50 and 66, it in this thin form covers the country, Chalky Clay and Chalk alike.

This, in my view, is the finer part of the spoil resulting from the melting of the surface of the eastern edge of the great mass of ice lying within the broken line after the shrinkage into the valleys to the east of it had taken place, and the Hoxne lagoon had disappeared. The volumes of water thus pouring over Norfolk being unable to escape readily by reason of the ice still occupying the valleys, the gravel which it produced by washing out the moraine, and the large flints which by its torrential force it rolled into the cannon-shot form described, were thus left on the plateaux and brows of the valleys, the large stones nearest the water source, and the smaller stones and sand carried furthest; but as the ice gradually wasted out of the valleys this spoil became deposited in their bottoms and on their slopes, forming in this way the beds *e'*, shown in the Wensum and Yare valley in figs. VIII. and IX. Hence the fact, otherwise so difficult of explanation, that these gravels form a series from the higher to the lower levels, and cannot be separated, albeit that the valleys thus containing them had been wholly excavated before their accumulation.

In its escape through the valleys, as the ice in wasting permitted it, this water denuded the Hoxne brickearth, forming or enlarging in so doing the lateral valley of the Goldbrook; and as it sank away it left the thin wrapper formed of gravelly sand which it carried over the denuded surface of the brickearth. During all this it must be remembered that the principal escape of the water was westward, in accordance with the different inclination of the land at the time.

The sheets of gravel that eventually accumulated in the valleys from this agency, and form, as I have said (if sections be selected from different parts of the area at different levels), an unbroken series with the beds on the plateaux, are so distributed that their relative presence and absence in closely contiguous areas in the same valley are explicable in my view on no other hypothesis satisfactorily, because, since we find that the Norfolk valleys had been excavated to more than their present depth before the termination of the Chalky Clay, it is obvious that gravel in them which rises, as some of this in the valley does, to 50 feet above the river at Norwich, cannot be due to the deposit of the rivers in a former more voluminous condition. That rivers during so much of the Glacial period as succeeded the ice-melting which I have traced, did occupy these valleys in greater volume than at present I fully concede; but in the east of Norfolk and north-east of Suffolk their gravels must be below the surface of the alluvium which now fills up these valleys, the sea-level in that part of England having been at, and for some time after the close of the Chalky Clay below its present line*. When the position of the Chalky Clay in the Norfolk and Suffolk valleys had not been detected, particularly the remarkable instance disclosed by the Norwich Sewer-works, the theory of the gradual erosion of the valleys by the action of a river from higher to lower levels seemed plausible, and the deposition of the gravels in a series extending from a higher to a lower level seemed *primâ facie* a reasonable hypothesis, as, whether true or not, it may still appear in areas outside the action of the newer Pliocene land-ice; but such an explanation seems to me quite to fail before the evidences connected with the East-Anglian valleys, which the researches of the past 10 or 15 years have disclosed, and we must, I submit, seek other explanations.

The flood-waters produced by the ice-melting, which I have described so far as I have traced it, seem to me to supply this explanation, were it not that there would, without some other, be as much difficulty in supposing these valleys, if the escape were free, filled with water from the ice melting up to this high level, as there would from the snow-melting of an ordinary arctic or subarctic land surface. Nothing, it seems to me, but an impediment to the free escape of it could have kept the water at levels necessary for the deposition of gravel in the otherwise inconsistent way in which we find it there, and this impediment the unequal melting of the ice filling the valleys seems to me to supply.

For instance, in the valley of the Yare, at Norwich, a little west of the line of fig. IX., the valley-gravel rises to a height of about 50 feet above the river, and is seen in the railway-cuttings carried through it, near the Norwich (Thorpe) station; but though at a much lower level than this, the clay *d* in the valley-bottom in fig. IX. shows no trace of gravel on it. Numerous instances of the like kind occur in this valley and in others of this part of England; and at Tharston in the valley of the Tese, a tributary of the Yare, a tumultuous accumulation of this gravel contains strips of the Chalky Clay imbedded in it.

The similar infilling of the Waveney valley by alluvium to that of the Yare, and up to greater height, as regards the floor of the Pliocene formations, conceals, as I have said, the evidences of these interglacial phenomena to a great extent there; but the chief part, if not all, of the gravel in the bottom of that valley appears to me to belong to this glacier-ice-melting, and not to the river. It forms an extensive sheet for some miles on both sides of Bungay, rising only some 10 or 15 feet above the alluvium; and an extensive sheet of it fills the valley of the Little Ouse, patches also occurring on the higher slopes †.

* During the depression of the east of England below its present level, which I shall, in the second part of this memoir, show took place during the formation of the *Cyrena* brickearth *f*", river-gravel may, however, have formed in these valleys, and be mixed up undistinguishably with *e*' in their bottoms.

† So far as land or freshwater shells may occur in these gravels (which it would seem, from a statement by Mr. Flower at p. 50 of the 23rd vol. of the Quart. Journ., has not yet been the case) we must remember that the Hoxne

In the valley of the Gipping the evidence is similar to that of the Yare. Thus there is no gravel over the Chalky Clay along the line of fig. I. A or in fig. XX.; but in fig. XIX., which is distant only $1\frac{3}{4}$ mile from it and half a mile from the line of fig. I. A, a thick bed of gravel lies against a low cliff of the Chalky Clay; and it is not to any sinking of the land, but to the rise of the flood-water from impediments offered to its escape by the ice in the valley, that I attribute the position thus occupied by the gravel.

The gravel thus bedded up to the cliff in fig. XIX. has a great development in this Gipping valley about Claydon, and thence northwards up the valley to Needham Market, a space of about 4 miles in length, extending high up the sides of the valley; but above Needham there is no such feature, what gravel there is being the Middle Glacial (*c*) cropping out from beneath the Chalky Clay by the valley denudation; while from Claydon seawards such gravel as there is in the valley lies at a much lower level, skirting the alluvium, and is part of that traced in Stage V. as indicating the position of the sea at the close of the Chalky Clay.

From this it would appear as if by some glacier ice remaining in the valley below Claydon, and blocking up the escape of the flood-water, this water accumulated in the upper part of the valley between Claydon and Needham, and when standing at the level of the top of the chalk in fig. XIX. wore away the clay cliff; after which, by the persistence of the dam, the waters from the ice-melting rose higher and bedded their gravel up to, and probably over, this cliff, and so up the valley as far as this arrested water extended; and upon the dam disappearing the water escaped too quickly to leave any of this gravel over the valley below, in its rush probably rather denuding than depositing. South of this valley we lose these features, and in the valley of the Blackwater traversed by the line of fig. VII. we seem to get evidence of the sea entering the valley as the glacier ice dissolved, and depositing sand and gravel over the moraine.

In this case the Chalky Clay cutting out the gravel *c* and occupying the bottom of the valley, passes up by very gradual change into a sandy brickearth, at first blue and full of chalk, and much like the clay itself for a foot or two, then becoming brown sandy brickearth for a few feet, and then almost as gradually changing to gravel. A section showing this at Appleford bridge (over the Blackwater, one mile north of the line of fig. VII.) was given by Mr. Harmer and myself in the 33rd vol. of the Journal, p. 111, and we were then under the impression that the clay in it was a bed at the base of the gravel *c*; but Mr. W. H. Dalton, of the Geological Survey, found, from a series of well-borings, that the clay in question is the Chalky Clay making the plunge which I have described as occurring

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bed containing these shows that the surface of the uncovered moraine was inhabited by them. Mr. Flower always, though without suggesting how, clung to the opinion of the palæolithic gravels of the Little Ouse district having been due to flood or cataclysmic action. See also last note.

generally in the valleys, and that therefore the gravel occupying that valley pretty uniformly up to a level of about 100 feet above Ordnance datum is not the gravel *c* cropping out from beneath the Chalky Clay, but gravel posterior to this clay.

The transition shown by this Appleford-bridge section from the Chalky Clay to the gravel which rests upon it in the valley-bottom seems, from the description of Mr. J. M. Wilson*, to be entirely analogous to that which occurs in the railway-cuttings near Rugby, in the valley of the Avon, where that gentleman describes this clay (which there makes a similar plunge into the valley of the Avon, cutting-out the gravel *c*) as changing imperceptibly into the quartzite gravel, which I am about to describe in Stage V. as extending over the western edge of the formation.

In the excavation of the trough, which is occupied partly by the upper portion of the Bain river, and partly by the Steeping river in Lincolnshire, however, we get what seems to me to be one of the most conspicuous results of the ice melting. This deep and steep-sided trough is formed on its north-east sides by the escarpment of the Chalk wold, shown by the dotted line in Sheets 83 and 84, and on the west by that massive deposit of the Chalky Clay rising to a nearly equal height with the Wold, of which I have spoken in connexion with the marl masses in Stage II. The petty streams of the Bain and Steeping which occupy it could in no conceivable conditions of climate have possessed the volume necessary to have wrought its excavation, even if the general facts pointed in that direction; but we have seen, in the case of the East-Anglian valleys, that rivers, so far from having had any thing to do with their excavation, have only filled them up to their present alluvium level. The excavation of this picturesque trough of the Bain and Steeping seems to me to have resulted thus.

The sections referred to in the footnote † will show that the head of this trough commences where the Chalky Clay is bedded up to and buries the Wold escarpment. This and the fact that the Wold forms one side and the Chalky Clay the other side of the trough, indicate that when the Chalky-Clay ice began to dissolve the clay lay continuously up to the escarpment along the line of the trough. The Wold itself is bare of the clay, the whole of the vast mass of the chalk degraded from it by the ice having been swept over its escarpment into the depressed area of Central Lincolnshire; so that what is nevertheless a part of the Chalky-Clay moraine consists of reconstructed chalk, pure enough to be burnt for lime. So long as the ice continued to move it kept up this supply of moraine from the Wold, and no fissure was allowed to form between the Wold escarpment face and the moraine thus swept over it; but when, from the diminution or cessation of the movement of the ice,

* Report of the Rugby School Nat. Hist. Soc. for 1873, p. 10.

† For the structure of these valleys, see sections of paper of Mr. Rome and myself in Quart. Journ. Geol. Soc. vol. xxiv. p. 161; also plate of sections accompanying paper by myself in Geol. Mag. for January 1878.

this supply either diminished or ceased, the water arising from the melting during summer found its way between this escarpment-face and the moraine, and having once done this, it, by the ever-increasing quantities pouring from the ice in its dissolution, soon swept out the clay, and washing it into gravel, contributed to that spoil of Lincolnshire, hard white chalk, which, together with the red chalk of the same county, is found in the Cotteswold gravels, presently to be described. Patches of the gravel resulting from the spoil of the Bain-Steeping trough still remain in it, as at Hagworthingham (where they cap low hills which were formed out of the Neocomian beds by this denudation), and they are of the cannon-shot kind.

The narrow spaces in Map No. 1 (Pl. XXI.) uncovered with the shading representing the Chalky Clay are the river-valleys of the region, the rivers of which are delineated in Map 2. These the ice in shrinking cut out. At the close of the Chalky Clay the sea lay to the west of it, deepening in that direction towards the Atlantic, and it lay in a shallower condition over a part of the German Ocean. Judging from the elevation of the gravel line resting on the Chalky Clay, the sea at this time still flowed up the Lea valley, and, but for the intervention of a space of higher ground near Dunstable, would have formed a strait between the sea in Sheet 1 and that in Sheet 46.

The water parting between the systems of the Ouse and Thames in Sheet 46, and that between the Nen and Avon in Sheet 53, appear at the close of the Chalky Clay to have just emerged ; but that between the Welland and the Avon (which is part of the Severn system), in the S.E. of Sheet 63, was still beneath the sea-level of that time ; and it was through the Welland valley and over this parting that material from the washing-out of the Bain-Steeping trough evidently was carried into the sea over the Severn system, and imbedded in the Cotteswold gravel in Sheet 44.

In the case of the valleys in Sheets 70 and 83, though all these, except such as lie in the extreme west of the sheets, now drain to the Wash, yet at the time of the ice-retreat this was, owing to the different inclination of the land, I consider, not the case; and since, as we have seen, the moraine entered the sea over the upper part of the Trent system by the valley of the Soar in Sheet 63, so did the sea enter the rest of the Trent system from the west as the ice vacated it, and the whole area of that system became occupied by the sea, so that this covered the Jurassic escarpments in the north of Sheet 86, but declined to lower elevations in the direction of the Wash, the line of the gravel *e* there falling nearly to the level of the existing sea-line. The principal, perhaps the only one of these valleys which has been thus reversed is that flat one of the Witham and its affluents, for it is along the valley of the Langworth, one of the affluents of this river as well as that of the Witham itself below its confluence with the Langworth, that this gravel line descends from the summit of the escarpments in the north of Sheet 83 towards the Wash.

In this direction, therefore, further part of the water from the ice melting probably escaped, passing out into the Trent basin instead of into the Wash.

The valley of the Cam, occupying as it does the space bare of the Chalky Clay that extends through the south-west and centre of Sheet 51, has evidently been all of it excavated by the ice of this clay; and I am informed that phosphatic nodules from the gault of this valley-bottom occur in the Chalky Clay overwhelming the island lying east of it, in Map 2. I shall attempt in the second part of this memoir to show that the valleys of all the rivers running through the area of the Chalky Clay to the Wash were entirely excavated by the ice which I have been describing, the rivers themselves having had no share in the process beyond removing (after or as the country acquired its present inclination) part of the gravels that first accumulated in them.

Stage V. *The Period of the Purple Clay of Yorkshire and of the Gravel e.*

Beyond those parts of Norfolk and Suffolk where the Cannon-shot gravel and other spoil of the ice-water occur, the Chalky Clay presents that invariably bald surface of heavy land which forms the principal wheat-growing area of England. Along the edges of the valleys through it there occur small patches of gravel occasionally, which rise to greater heights westwardly, until along the edges of the formation nearest to the sea of the period we find it more generally overlain by gravel. The places where this occurs are those where the ice at the close of the formation entered the sea. In the north of Sheet 48, where the line of the sea-level of this period begins to rise above that of the present day, we do not find this gravel (*e*) overlapping the Chalky Clay so as to rest upon it, but only as forming a sheet immediately below the lowest or plunging part of the clay, in the manner shown by figs. I. and I. A, and here it reaches the elevation of about 25 or 30 feet. As it extends due westwards, however, through Sheet 48 up the valley of the Stour, this gravel covering continuously the wide valley-bottom gradually rises in accordance with the westerly increment to an elevation of 60 feet before reaching the boundary between this sheet and that numbered 47. Proceeding southward we find it continuous with *c* to the east of the (*Essex*) Colne in the south of Sheet 48, while to the west of that river it lies outside the flat-topped tablelands, covered with the gravel *c*, to which the moraine did not reach. Separated from *c* by a denuded slope of London Clay, it lies between it and that part of the gravel which is marked *f* in fig. VI., and which skirts the coast in Sheet 2, and touches in Clacton and Holland cliffs, at a low elevation, the south centre of Sheet 48 before disappearing in the North Sea. As it sweeps into the estuary of the Blackwater it is shown at the eastern extremity of fig. VII.; its elevation at Tolleshunt, which is beyond the limit to which the moraine reached, corresponding with that it reaches over the moraine at Braxted. Entering the valley of the Blackwater this gravel there passes over the Chalky Clay where this accumulated, after the change in the mode of deposition which I have described, from the mudbank to the cutting-out method, in the bottom of that valley. Here, in the Blackwater issue of the ice to the sea, it lies at a height of about 100 feet*. It enters the valley of the Chelmer, the next river south of the Blackwater, and there passes undistinguishably into the lower part of the gravel, which extends up the northern and eastern slopes of Danbury hill to the summit; for the Chalky Clay not having reached those sides of this hill, the formation of gravel there went on uninterruptedly, so that *b'*, *c*, and *e* are continuous, as, but for the interposition of the Chalky Clay, they would be on the western slope of the ridge in fig. VII.

Along the northern slope of the Thames valley small patches of gravel occur at various heights, representing that which, having accumulated there while the Chalky Clay was forming, was mostly washed away before it emerged. Of these one at Laindon Common is traversed by the line of fig. VI.; and they also occur above the edge of the Chalky Clay in valleys tributary to that of the Thames, such as that of the Roding, in those places where having emerged, and the ice not having reached so high or so far, this has not destroyed them. None of these, however, pass over the Chalky Clay; but in the railway-cutting through the hill above Chipping Ongar, in the fiord or channel represented by the Roding valley, a considerable bed of gravel was exposed, resting on the Chalky Clay that had been deposited by the ice which ploughed out that channel. This is the lowest point to which the clay descends the side of the Thames valley, or of any offset from it, such as that of the Roding, and its elevation is nearly level with the 175-feet mark on Ongar station. This is in the Roding issue to the sea.

Mr. Prestwich, in vol. i. of the 'Geologist,' p. 241, describes the Chalky Clay as both overlain and underlain by gravel in the railway-cutting at Brickett Wood, near the centre of the north part of Sheet 7. The elevation of this cutting is about the same as Brickett-Wood station, which is 256 feet. This is in the (*Hertfordshire*) Colne issue to the sea.

In the west centre of Sheet 46 I found the Chalky Clay overlain by from 3 to 5 feet of red gravel on the hilltop at Southend Stewkley in a clean section. This point is on the summit of the water-parting that here divides the drainage-system of the Ouse from that of the Thames, and its elevation is 482 feet; but as it forms a small island in Map 2 (Pl. XXI.), occupying the centre of the opening represented by those portions of this parting which are below or but little above the line of the junction of *c* with *d* in their vicinity, and the gravel was very coarse and flinty, I do not regard it as a part of that which I am now describing, but as having been derived from the melting of the ice that had mounted this island, and lay high above the sea, and as similar to that of Norfolk described in Stage IV. (*e'*). The channels which here had, at the stage of emergence shown in Map 2, connected the sea over the

* Freshwater shells have been found in some of this gravel near Braxted; but, of course, as the sea retreated by the further rise of the land, the fresh water followed it.

Thames system with that over the Ouse system were on either side of this island; and in one of these, at Winslow-station brick-field, I found that the Chalky Clay (underlain by *c*) had over it a bed of gravel full of quartzite pebbles. The Ordnance mark denoting 277 feet elevation is on the bridge near this brickfield; but as Winslow is at the head of the Ouse drainage-system, and the parting between this system and that of the Thames, though open (by way of the Ray, at least) at the time represented by Map 2, had, I think, emerged by the close of the Chalky Clay, the gravel over the clay here, though of the same age as *e*, does not occupy, as in the cases just mentioned and those about to be mentioned, the actual issues of the ice of the Chalky Clay to the sea at the close of that formation.

Mr. Lloyd, in describing the Drift of the Avon valley, gave the elevation of the quartzite gravel there in Sheet 53 as reaching 386 feet*. He does not, however, distinguish to which of the gravels that he groups together as the Older Drift of this part this elevation applies; but from the notices of its occurrence around Rugby, given by Mr. Wilson in vol. xxvi. of the Journal (p. 192), particularly at Cawston, Clifton, Shawell, and Newton, it would appear that the gravel over the Chalky Clay in the north-east of this sheet ranges nearly or quite to this height (the clay there being also underlain by the gravel *c*), while at a lower elevation it caps the clay plunging from this position into the valley of the Avon and cutting out *c*; for it is described by him, in the report of the Rugby School Natural-History Society for 1873, as there passing imperceptibly downwards into the Chalky Clay, just as I found it in similar position in the Blackwater valley crossed by the line of fig. VII. This is in the Welland and Avon issue, the deepest and broadest apparently of all the issues of the ice to the sea, except perhaps that of the Trent.

Proceeding from this part directly towards Moel Tryfaen, we get, at Birmingham, near the centre of the south of Sheet 62, the section of Messrs. Crosskey and Woodward, which I have copied in fig. XVII. Here the gravel *e* appears to reach the elevation of 520 feet. This seems to be in the (reversed) Trent issue.

In all this, both in the direction southwards from Sheet 48 and westwards from Sheet 1, we find the increment of submergence so far agreeing with that traced at the end of Stage II. that, from the part where this gravel rises above Ordnance datum in the north of Sheet 48 to the place of Section XVII. being 140 miles and the rise 520 feet, it gives a westerly increment of 3·7 as against the 4·5 feet per mile in Stage II., while from the same point to Ongar cutting, in Sheet 1, the distance being 70 miles and the

* Quart. Journ. Geol. Soc. vol. xxvi. p. 216. The gravel reaching this elevation is that distinguished by Mr. Lloyd with the letter A. Mr. Lloyd's bed B, where it occurs in the Lias districts, is the Chalky Clay, and elsewhere it may be its marine equivalent, as may also be his C. His D is the Middle Glacial (*c*). All these he puts together as the Older Drift; and his other, or Newer Drift, indicated by succeeding letters, is that of stages subsequent to this portion of my memoir.

rise 175 feet, it gives for the south-westerly increment 2·5 feet per mile, or the same as that traced in Stage II. From this limit in Sheet 62 the line of the gravel *e* falls in a corresponding way towards the Wash. In Sheet 63 its elevation seems much the same as in 53, and for it I rely on the observations of Mr. Harrison, of the Leicester Museum, who has kindly done some field-work for me there, and whose measurements of altitude have been by aneroid. Here also *c* is much preserved beneath the Chalky Clay, cut through, nevertheless, by the plunge of the clay into the valley of the Soar, in accordance with this feature, as I have described it elsewhere. The highest point at which he found gravel was Saddington, 464 feet. This, however, may perhaps be the gravel *c* emerged before the moraine reached it and left uncovered by it, or it may be the gravel *b'*, or possibly, as it is on one of the islands in the south-east of the sheet*, gravel of the ice melting (*e'*); but at 376 feet, at Kibworth, was a section of sand and gravel uncovered by the Chalky Clay, and containing masses of that clay imbedded in it. In the various sections which he found, only those at Oadby, in the east centre of Sheet 63, at 320 feet, showed the Chalky Clay clearly overlain by sand or gravel, which in one instance lay irregularly several feet deep on the clay, while in another the clay passed up into a sandy bed full of quartz pebbles and flints, which agrees with the description Mr. Wilson gives of the passage upwards of the Chalky Clay into the quartzite gravel near Rugby. In this district the gravel lies close up to the water-parting between the Welland and Avon at Husbands Bosworth, as well as to the partings between the tributaries of the Soar, a part of the Trent system, and those of the Swift, a part of the Severn system, and maintains much about the same elevation which it does around Rugby.

Mr. Mackintosh mentions finding the Chalky Clay on the Triassic escarpment near Gainsborough (in the north-west of Sheet 83) passing up into quartzite gravel†. This clay, I presume, is an extension of the patch shown by me in the south-west of Sheet 86; and the gravel, like that crowning the Jurassic escarpments in that sheet (but most of which rests on the Jurassic rocks directly), to be the deposit of the sea entering the drainage-system of the Lower Trent after its vacation by the ice.

North-east from 63, through Sheet 71, and as far as the west of 70 (in consequence of failure of health before I could work this area) I have not been able to collect other evidence as to gravel covering the Chalky Clay. In the centre of Sheet 83, however, Mr. Rome and I found an extensive formation of gravel setting in at the western edge of the westernmost of the two lines of small patches of the Chalky Clay running northwards through that sheet and spreading out extensively in the west of Sheet 86, where, as just said, it crowns the Jurassic escarpment. This begins a little north of Lincoln, in the valley of the Langworth, at an elevation of less than 100 feet, whence it rises northwards. It seemed to pass

* See Note, p. 527. † Quart. Journ. Geol. Soc. vol. xxxvii. p. 185.

over the Chalky Clay (for there is generally none under it in this region*), but we found no section to show this distinctly except at Langton, near Wragby; but the greater part of its range is where none of this clay has been left.

As this gravel extends north-westwards it rises gradually, so that in Sheet 86 it crowns the escarpments at elevations exceeding 200 feet, as described by Mr. Rome and myself in the 24th vol. of the Journal, having there been called by us "Denudation gravel," under the somewhat erroneous idea that it was connected with the denudation of the Chalky Clay. From central Lincolnshire towards the Wash the line of this gravel descends through the valley of the Witham to very low elevations, so as to become undistinguishable from the line of that surrounding the Wash, which is to be described in the second part of this memoir.

Within this circuit of gravel and above its line of elevation the Chalky Clay everywhere, save where patches of gravel of the kind described in Stage IV. occur, presents a naked surface, which could not be the case if submergence in general had succeeded its deposition.

A comparison of the elevation of the line of gravel *e* with that of the gravel *b'* should show the rise of England in the interval; but in the neighbourhood of the Chalky Clay, *b'* caps only isolated hills, the depth of water over which at the culmination of the submergence we have nothing beyond the general increment of depth westwards and southwards to show. Thus in fig. VII. *e* is less than 200 feet below *b'*, but it is 260 feet below *b'* on Danbury hill, which forms a promontory on the north side of island No. 3, and is only 7 miles to the south-west of fig. VII. At Ongar, *e* is scarcely 200 feet below the patch of *b'* which I found on Warley hill, while it is 265 below that on Hampstead. If, however, we compare *e* at Ongar with *b'* nearly 26 miles due south of it, on Well Hill, *against the unsubmerged summits* of the chalk downs close adjacent, such as those at Knockholt, and allow for the southerly increment which I have estimated at the end of Stage II. as a little over 2·5 feet per mile, it gives a difference of a trifle over 300 feet. If we compare *e* at Brickett Wood in the Colne issue to the sea at 256 feet with *b'* on the skirts of the Chilterns at 600 feet or thereabout, and allow for the westerly increment, we get a difference of about 250 feet; but I have not been able to ascertain with any precision the highest points reached by *b'* in that position, and it may be more than 600 feet. Comparing *e* at 380 feet around Rugby with the highest level at which gravel actually occurs on the Cotteswolds, we get a difference of about 370 feet, but if the westerly increment be taken into account, of 280 feet only.

The further west, however, that we institute the comparison the more do we approach the conditions of an increment of *northerly* depression, such as is deduced in Stage II. between South Hants

* At two or three places (Ranby, Market Stainton, and Brough-on-Bain) in this neighbourhood there are patches of gravel which is either in or under the Chalky Clay or is part of the first spoil produced by the washing-out of the Bain-Steeping trough; but they are of very small extent indeed.

and Macclesfield, and lose that of the opposite direction, so that the terms of comparison become obscure. Thus the westerly increment of 4·5 added for the 30 miles distance, at which *e* in fig. XVII. lies nearly due west of Rugby, would make the elevations of *e* at Rugby and Birmingham closely coincide, the elevation of *e* in fig. XVII. (judging from that of the canal mentioned by Messrs. Crosskey and Woodward) being about 520 feet. A comparison, however, of this latter with *b'* on the Cotteswolds at 750 feet, without any allowance for southerly or westerly increment (the two places lying nearly on the same meridian), would show a rise during the Chalky Clay of only 230 feet; but as the place of fig. XVII. and the Cotteswolds are both in the line from Macclesfield to South Hants, along which in Stage II. I have described the northerly increment of 4·5 feet per mile as obtaining, and fig. XVII. is 25 miles nearer to Macclesfield than the northern extremity of the Cotteswolds, an allowance at this rate would augment the 230 to 342.

On the whole we may, I think, take 300 feet as a very close approximation to the true amount that England rose between the culmination of the submergence and the time when the ice of the Chalky Clay began to retreat and make room for the deposit of *e* over its moraine in the part where it had issued to the sea; and though we cannot suppose this rise to have been precisely uniform over the whole of England, it is, I think, clear that no considerable recovery from the preponderance of westerly depression had up to this time occurred. This amount of emergence would have brought central Norfolk to its present elevation, as deduced in Stages II. and IV., East Norfolk being higher than this, but West Norfolk lower.

The elevation of *e* around Rugby, extended with the increments just discussed to the water-partings in question, would show that at the close of the Chalky Clay the water-parting between the Thames system by way of the Cherwell and that of the Severn by way of the Itchen or the Leam (branches of the Avon in Sheet 53), which lies at an elevation of about 450 feet, had emerged, and that the parting by the way of the Evenlode and the Stour (tributaries of the Thames and Avon) in Sheet 44, which lies at a very similar elevation, could have had but little water over it. Nevertheless the passage over it, which I have to describe, of the red and hard white chalk from the washing-out of the Steeping trough described in Stage IV. (the red chalk at least, when *in situ*, being confined to Sheet 69 and the sheets north of that) shows that there was water enough to float ice of some sort; and the difference between the elevation of this water-parting and the elevation up to which the submergence of the Cotteswold during Stage II. clearly extended is just about 300 feet. The parting (on the south of the Cotteswolds) between the Thames and Severn systems in Sheet 34, by way of the Swillbrook and *Somersetshire* Avon, and which rises to about 300 feet, remained open until later; but the emergence of this is connected with the events to which the concluding part of this memoir has reference.

The evidences afforded by the Cotteswold gravel in Sheet 44 are important in their bearing upon the events which I have been tracing. In the excavation of the tunnel at Mickleton, at the northern extremity of the Cotteswolds, a bed of gravel was found 87 feet thick, which reposed on 15 feet of clay containing large blocks of marlstone*. This bed of gravel was accumulated in a strait which divided the small island formed by Ebrington Hill, shown in Map 2 at the northern extremity of the large island which the main Cotteswolds then constituted, and the elevation of its top is 490 feet. It of course represents the entire gravel accumulation from the time when during Stage II. Mickleton became submerged, up nearly to the close of the Chalky Clay, a little before which its top had emerged; for from Mr. Gavey's description, it does not appear that this gravel contained the red chalk and hard white chalk of Lincolnshire, though Mr. Lucy mentions (p. 47 of his paper†) that patches of gravel with white chalk and flints are within the district where this bed occurs; and in one pit of which he gives a section, at Little Woolford fields, at an elevation of 394 feet, and in which 17 feet of this gravel is exposed, he found both the red and the hard white chalk imbedded in it, as well as the large angular flints so characteristic of the Chalky Clay. This is on the north of the water-parting between the Thames and Severn systems by way of the Evenlode and Stour, and in the valley of the latter. Near Chipping-Norton Railway Junction, however, which, though at a somewhat lower level than this last, is on the south of this parting and within the valley of the Evenlode ‡, he also found this débris; and as it has not been noticed within the Thames system further east, the inference is that passing from the mouth of the Bain-Steeping trough, in Sheet 84, it was swept by field-ice through the valley of the Welland and over the water-parting between this and the valley of the Avon, and so into the sea over the Severn system. Grinding along the coast of the islands shown in Sheet 53 of Map 2, but which had then further emerged so that the channels there shown as open between the systems of the Nen and Severn by way of the Leam and of the Thames and Severn systems by way of the Itchen and Cherwell had now closed, this ice was swept up the valley of the Stour to the east of Ebrington Hill and of the now emerged strait between that hill and the Cotteswolds, and so through one or two narrow and shallow passages through the parting which were still water-covered into the sea over the Thames system. The closing of the parting between the Thames and Ouse systems in Sheet 46, which I have described as having just preceded the end of the Chalky Clay, is quite in accord with these inferences.

The gravel which occurs abundantly within the drainage-system of the Severn has yielded molluscan remains in many places, and all of the same character; but with the exception of the band of fragments and worn shells which I have referred to the ploughing-

* Gavey in Quart. Journ. Geol. Soc. vol. ix. p. 29. † *Loc. cit.* p. 475, *antè*.
‡ The position of each of these occurrences is shown by the crosses in Sheet 44 of Map 2.

out of a sea-bed which had been in existence throughout most of Stage II., the gravel *c* has not yielded these remains; and as none of the remains from the gravels of the Severn system have come from them at elevations great enough (when we take into account the rise of its level from the westerly increment of submergence) to correspond with *c*, or even with the gravel (*e*) over the Chalky Clay, we may infer that they most probably, though not necessarily, belong to the period embraced in the second part of this memoir. Their character does not assist in this determination, for they differ in no essential way from the shells at Moel Tryfaen and other places of extreme elevation, all of which are those of Mollusca living now in the eastern part of the North Atlantic, and comprise none of those species which so clearly show the Bridlington and Dimlington beds to belong to the earlier part of Stage II.

Another subject also requiring notice before I proceed to the examination of the morainic formation of Stage V. is the absence of drift on the eastern slope of the Pennine, south of the Aire, at any altitude at all corresponding to that at which it occurs on the western slope. This has been long known, and it forms the subject of a special examination in the Geological-Survey memoir for Sheets 81 E. and 71 S.E. Where the Pennine is breached by the valley of the Derwent in Sheet 81, and of the Calder in Sheet 88, drift extends up those valleys to increasing heights westward*, though not (so far as it would appear from the Survey memoir) to heights so great as that at which the highest Macclesfield patch occurs on the west slope, and, as I have already said, some special set of the currents has been invoked for an explanation of the phenomenon. On the other hand, near the line dividing Sheets 88 and 92, glacial drift is said to be present, and to rise to very great elevations on the eastern slope, and so continue northwards†. It is over this part, close to the division line of Sheets 97 and 102, that the blocks of Shap granite have travelled from the western slope of the Pennine and across the watershed. This transit has occurred at elevations between 1400 and 1500 feet, if not, indeed, somewhat higher; and what is very important to observe is that this transit has not occurred by several routes which traverse the watershed at lower elevations than this, down to one as low as 800 feet. These routes all lie in Sheets 93 and 97, and are given in detail in my paper on the Boulder-clay of the North of England in the 26th vol. of the Journal, p. 109. In that paper (labouring under the error as to the time of the great submergence) I attributed the passage of these blocks to the agency of floating ice at the period of greatest submergence (a view which I no longer entertain either as to agency or period), and suggested that the only explanation of these blocks not having travelled by the lower routes, that I could see, was that these routes were blocked by ice. In the same paper I pointed out, as the fact is, that these blocks do not occur in the Chalky Clay, but are confined to the Purple; and under

* Dakyns, Quart. Journ. Geol. Soc. vol. xxviii. p. 382.

† Dakyns, *loc. cit.* See also Curry in Quart. Journ. Geol. Soc. vol. xxxiii. p. 40.

the same error as to the time of the great submergence I attributed the succession of that clay to the Chalky to its having been formed by the extrusion of moraine from the same ice as that of the Chalky Clay, under an increased submergence of the country, which had caused this ice to recede from the Chalk Wold, and so put an end to the Chalky Clay. This view of the cause of the succession, and of its attendant conditions, I also, as the preceding pages show, do not now entertain.

Very shortly after this paper, the late Prof. Harkness entered very elaborately into the subject of the transit of the Shap blocks*, contending for their transit by floating ice, when the Pennine stood more than 1500 feet below its present level. On the other hand there are geologists† who have entertained the opinion that this transit was effected not by floating but by land ice, a view that, as appears in the sequel, I have now seen reason to adopt. All those geologists who have studied the glacial phenomena of the North-west of England appear to have thought that the great submergence indicated by the Moel Tryfaen and Macclesfield shell-gravels followed the glaciation of that part of England, and the formation of the Lower Boulder-clay of Lancashire and Cumberland (with which, in my view, the Purple Clay of Yorkshire is identical), and that with this submergence the glacial conditions passed away, except so far as the Upper Boulder-clay of that region indicated their renewal. My own view also up to the time when, three years ago, I first tried to grapple with the subject of this memoir by examining and collating analytically all the evidence concerning the newer Pliocene formations which I had, during many years' work upon them in the field, collected, was the same; and the principal thing which influenced me in this opinion was the character of the molluscan fauna found in these formations. It was not so much the remains found in the seam near the top of *c* that influenced me (for, as already explained, these, I think, have been ploughed out of a sea-bottom which began to form during the earlier part of the long period of Stage II.), but those which occur at Bridlington, and more especially those of the seam of sand in, but near the top of, the Basement clay of Holderness at Dimlington, where its junction with the Purple Clay which overlies it is displayed in the cliff.

This seam was detected by a party of geologists consisting of Sir Charles Lyell, Mr. Leonard Lyell, Prof. T. M. Hughes, and Mr. Rome; and a description of it was sent to me by Sir Charles Lyell with the molluscan remains which they extracted. These remains, especially those of the *Nucula*, were, many of them, broken, though freshly fractured and unworn; but the written description sent me with them was that they were taken from a seam of dark sand *literally packed with perfect specimens of Nucula Cobboldiæ*, which seemed to be double; and this was certainly the condition of one of the bivalves (*Astarte compressa*) which was sent to me.

The Bridlington bed has been long known, and was described by

* Quart. Journ. vol. xxvi. p. 517. † Goodchild, *ibid.* vol. xxxi. p. 98.

Mr. Rome and myself*, and again in a vertical diagram by myself†, as intercalated in the lower part of the Purple Clay, the Basement Clay appearing to us to die out some miles south of Bridlington. It is now, however, said‡ that the latter extends to Bridlington, and occupies the space there between the beach-line and the chalk floor, a depth of between 30 and 40 feet; and that this long-known shell-bed rests *on its surface* and beneath the whole of the Purple Clay, which just there must be in less thickness than at Dimlington. From this it would appear that unless the clay at Bridlington has been planed off, the shell-bed here and the one at Dimlington occupy precisely the same horizon in the newer Pliocene sequence of deposits. Now the Bridlington shells unquestionably lived where they occur, for they are in the most perfect preservation; and though the sand containing them has, in the specimens I possess, hardened to the condition of rock, the bivalves have both valves adherent and are quite unworn. This fauna, while it presents certainly the most arctic appearance of any known from England and perhaps from any part of Britain, contains the peculiar and now extinct forms *Tellina obliqua* and *Nucula Cobboldiæ*, the first a shell which, appearing rarely in the Coralline Crag, and so rare in the Walton part of the Red Crag as to be almost unique, becomes more common in this crag between Walton and Butley, while at the latter place, and also in the fluvio-marine crag, the Chillesford bed, and the sands *b 1*, where these are fossiliferous, it swarms. The *Nucula* is quite unknown in the Walton portion of the Red Crag, but it is abundant in the Butley and fluvio-marine portions, and occurs in the sands *b 1*. Both species are not only extinct, but the nearest living analogues of the *Nucula* are confined to the North Pacific Ocean. Besides these there occurs at Bridlington a North-American species (*Venus fluctuosa*) unknown from the Crag, or any other British bed, glacial or otherwise, except that next mentioned. Of these three shells I have found the remains somewhat common in the seam near the top of *c* (shown by the letter *x* in fig. XIII.); but they are unknown from any other glacial or post-glacial bed in Britain, with the exception of the sand *b 1*, which yields the two first-mentioned of them.

Now if the beds of Moel Tryfaen and Macclesfield which contain none of these three species, nor any not still living either in British seas or in those immediately north of Shetland, nor yet a fauna of a character at all so arctic as that of Bridlington, but yet were obviously accumulated when submergence was at its greatest, are older than these of Bridlington and Dimlington, it is a very anomalous circumstance. These three species are equally unknown from the Hessle and Fen gravels of the eastern side of England, which contain no species but such as now live in the sea surrounding the British isles, or in that immediately north of the Shetlands, and yield a molluscan fauna quite as different from that of Bridlington and Dimlington as that yielded by Moel Tryfaen, between which and the fauna of the Hessle gravel there is no difference

* Quart. Journ. Geol. Soc. vol. xxiv. p. 149. † *Ibid.* vol. xxvi. p. 90.
‡ Lamplugh, in Geol. Mag. for Nov. 1878, p. 509, and for Sept. 1879, p. 393.

of any essential character beyond the fluvio-marine admixture in the latter; and this negatives any explanation of the difficulty by supposing that the species in question were peculiar to the eastern side of England.

It will, I trust, appear clear from the preceding pages of this paper that the general submergence preceded the formation of the Chalky Clay; and had I space I could offer many reasons to show that it preceded both the Purple Clay of Yorkshire and the Lower Boulder-clay of the north-west containing shells; and I think it must, from what I have shown, be obvious to geologists that the Basement Clay of Holderness was formed when the inclination of England was in accordance with that which prevailed at the commencement of Stage II., and when the extinct Mollusca which are found in it still survived from the time of the Crag in the continuation of the sea of which, while still confined to the eastern side of England, the Bridlington and Dimlington shells lived. Had the Purple Clay and the Lower Clay of the north-west been followed by the submergence, the gravels which then accumulated up to 1200 feet in Lancashire, and 1350 in North Wales, would everywhere rest upon it; but in the case of the Purple Clay there is no marine gravel at all over it, save the Hessle, which is at very low elevations; and in the case of the clay of Lancashire, none, so far as I can learn, at levels above that of Macclesfield Cemetery, which is given by Mr. Darbishire as 600 feet, and is less than that to which the gravel *e* should, by the westerly increment of submergence beyond the place of fig. XVII., rise. As regards moraine accumulated in the north-west during the sinking of the land in Stage II. I will speak further on.

As from the altering inclination of the land and increasing submergence in the westerly direction, the ice, of which the Basement Clay of Holderness was the moraine, and which had furnished morainic material to the sand *b 1*, and so gave origin to the Till of Cromer (*b 2*), retreated through the Humber, the Basement Clay became covered by the sea to a considerable depth, during which the Bridlington bed was laid down upon it. The seam at Dimlington was probably buried by a temporary advance of the ice and of its moraine during this retreat, and molluscan remains of the same period were preserved in the bed of the sea, which had now extended over Western Norfolk; and as the ice began, with the rise of the land, to advance in a different direction, in accordance with the changed inclination, it ploughed off such of these deposits, corresponding in age with the Dimlington and Bridlington beds, as lay in its path, and their débris, carried away by currents, was imbedded again in the gravel *c* in the way described in Stage III.; and thus it is that we get in the seam *x* in fig. XIII., the peculiar shell of Bridlington, *Venus fluctuosa*, and those other shells of that place which, before the culmination of submergence, had become extinct, such as *Nucula Cobboldiæ* and *Tellina obliqua*. These, together with several other Crag species found in the seam *x*, though they had disappeared from British seas when the submergence culminated, were yet living there in the earlier portion of that very long interval which is embraced by Stage II., during which this molluscan fauna changed to that found at Moel Tryfaen.

The distribution of the Chalky Clay indicates that the ice to which it was due came along the western side of the Wold only; for, after crossing the Wash, it overwhelmed so much only of island No. 1 as lay in the direction of this path. Had this ice descended the eastern side of the Wold, it would, we may infer, have overwhelmed all that part of island No. 1 which occupies Sheet 68; but this the ice has, so far as it lay outside the track along the west of the Wold, avoided. That such was the case is rendered more probable also by the fact that all the chalk degraded from the Lincolnshire Wold has been swept westwards into the depression of central Lincolnshire, while no trace of the Chalky Clay appears on its eastern side. The escape of the Basement Clay of Holderness from destruction by ice of the Purple Clay, I attribute to this ice having, where the Basement-clay occurs, terminated in the sea, and being thin there, so that the buoyancy of the water prevented that destruction which the ice of the Chalky Clay, where it eventually collected in very thick mass within the broken line of Map No. 1, has caused.

As by thus dissociating the Basement Clay of Holderness from the Chalky Clay we lose the test of superposition, it becomes necessary to examine how far, or whether at all, this Purple Clay may be a separate formation from the Chalky. Among the reasons for regarding them as distinct are the following:—

(1) The Purple Clay at elevations below 100 feet contains, in its lower part at least, lenticular beds of gravel and sand, the Chalky Clay being destitute of any thing of the kind. This feature, however, I can only assert positively of that arm of the formation which lies east of the Wold and Eastern Moorlands.

(2) The constitution of the two clays differs, the Purple Clay being crowded with small subangular débris of various hard rocks (principally from the Eastern Moorlands), while angular débris, other than flint, is very rare in, and, indeed, in most parts quite absent from, the Chalky Clay.

(3) The presence in the Purple Clay of the shap-blocks, which, from a late communication*, appear to occur at the base as well as in the upper part of it. These blocks seem to occur very nearly as far as this clay extends, but no further, the southermost known being one in the west centre of Sheet 87, which is mentioned in the Geological-Survey memoir for that sheet. They are wholly unknown from the Chalky Clay and from the area occupied by it.

The position of the Purple Clay is as follows:—It first shows itself above the sea-level in the small and low cliff of Cleethorpes (in the south of Sheet 85); and the excavations for the Grimsby Docks, close at hand, proved it to descend there to a depth of 102 feet below high-water mark, and to rest on the chalk direct, except in places where it had a few feet of chalky gravel beneath it. Northwards from this it forms the continuous coast-section of South Yorkshire (in Sheets 85 and 94), and there rests on the Basement

* Lamplugh, Geol. Mag. for Sept. 1879, p. 396.

Clay already referred to, wherever this rises above the beach. Its elevation in this part does not exceed 100 feet. On the line dividing Sheets 94 and 95, however, it suddenly rises with the chalk and covers that point of the Wold which projects to form Flamborough Head, and near this it envelops the crest of the escarpment at an elevation of 400 feet. It is here confined to a narrow strip of land skirting the coast, which varies from half a mile to three miles in breadth *; but to the south, in Sheets 94 and 85, it spreads out over the lower ground so as to reach Hull, in excavating the docks of which town it was found to descend to 70 feet below the sea-surface, and to rest at that depth on gravel, as in some places it did at Grimsby; but between Hull and Hessle, a space of four miles, it disappears, and as the chalk rises at the latter place, the Hessle sand and clay (which overlay the Purple Clay in the dock-excavations) only are present. Its western edge is mostly overlapped and concealed by the Hessle Clay, resting against the eastern slope of the Wold. From the narrow coast-strip which envelops the Wold escarpment it extends continuously northwards along the coast, lying irregularly on the slopes, and filling old valleys and hollows of the Jurassic rocks, and so enters the valley of the Tees on the borders of Sheets 103 and 104, up which valley it extends, skirting the northern slope of the eastern moorlands, and covering it up to elevations of about 400 feet. Filling the Tees valley, it passes over the watershed between that valley and the depression of central Yorkshire, which is drained by the many rivers which converge to the Humber, and which depression it occupies as far south as the low grounds skirting the Humber in the north-east corner of Sheet 87, beneath which it disappears, but shows itself again in the north-east of Sheet 82; in the cuttings between Bawtry and Retford clay like it overlies sand and gravel. Throughout Sheets 85, 86, and 94 it is purple in colour towards its base, where it contains a moderate proportion of rolled chalk, but is far more copiously charged with small angular and subangular rock-fragments; and it gradually parts with the chalk débris upwards, becoming, as it does so, more of a red colour; and it does precisely the same thing in a horizontal direction as it rises over the Wold along the coast-belt, the clay enveloping the Wold and its scarp being similar to that which forms the uppermost portion only of the clay in the lower grounds of Sheets 94 and 95. In the buried ravines of the chalk intersected by the cliff about Flamborough Head it is underlain by clay of a blackish colour, which, again, is underlain by (and sometimes interbedded with) beds of chalky sand and of gravel, and by beds of rolled chalk only, all of which seem to be of the age of the Holderness Basement Clay. At Dim-

* Mr. Rome and I mentioned the occurrence of some very small patches of clay on the higher parts of the Wold near the dividing-line of Sheets 93 and 94, and we referred them to the Purple Clay. One of these, at Huggate, was afterwards, with the object of seeing if it contained shells, excavated under the direction of Sir Charles Lyell. The clay was full of chalk, but no molluscan remains occurred in it. Some small patches also occur on the Lincolnshire Wold, and they all appear to me now to be remnants of moraine formed during the accumulation of *b 2*.

lington and those other parts of the coast-section in Sheets 85 and 94 where its base rises above the beach, it is underlain by alternate sheets of Purple Clay and of the blue Basement Clay, both containing rolled chalk, but which in some places are separated by beds of dark sand; and just below these is the position (as it was described to me) of the Dimlington bed of shells. In the vale of the Tees, and in that of Central Yorkshire, it seems often to be made up of reconstructed Lias shale and clay, finely laminated in places.

The position which the Purple Clay thus occupies is not one which, as a whole, is reconcilable with a marine deposit, though some of its features, nevertheless, point in that direction. Being thus dissociated from the Chalky Clay, but nevertheless overlying the Basement Clay and the beds containing the Dimlington and Bridlington Mollusca, we may regard it as either anterior to, synchronous with, or posterior to the Chalky Clay.

If anterior, it would belong to the later part of Stage II., and thus to the period of greatest submergenee, and be due to ice coming from the north (for to ice coming in that direction this clay on the east of the Wold is clearly due), after the ice of the Basement Clay had retreated through the Humber. The absence of any marine conditions in connexion with it above the level of, say 100 or 150 feet, however, and the absence of any gravel over it that could be referred to this period, seem to render this supposition untenable—the only gravel that overlies it along the Yorkshire coast-section, except some mounds on the edge of the chalk-escarpment in the south-east of Sheet 95 (and which appear to have been due to the melting there of the Purple-Clay ice, as the cannon-shot gravels were to that of the Chalky-Clay ice in West Norfolk) being the Hessle, and gravel even later than that, and these gravels are confined to levels below 100 feet.

If synchronous with the Chalky Clay, the part west of the Wold should be continuous with that clay, though, the part lying east of the Wold being due to an independent arm of ice, the absence of this continuity has not the same significance. There seems, however, to be a hiatus between this western part and the Chalky Clay, which dwindles away northwards by a chain of small patches decreasing in that direction, while nothing like a transitional character is assumed by the clays as they approach each other. Moreover, while the Chalky Clay all over that part of its range which is nearest to the Purple rests on the Mesozoic formations directly, and in places has the gravel *e* over it up to the level which I have described as falling towards the Wash, the Purple Clay appears to pass over that gravel in the railway-cuttings between Retford and Bawtry, in Sheet 82.

I therefore think that, though the eastern arm of the Purple Clay, which is that in which the Shap blocks abound, may be, and probably is, though unconnected with it, at least partially coeval with as well as later than the Chalky Clay, the western arm is posterior to it, and represents moraine which, after the ice of the latter had disappeared and allowed the sea to enter the area of the Lower-Trent drainage-system up to the level to which the progress of the emergence in that part had by this time brought it, came down between the Pennine and the western side of the Wold, as an offset from that which, crossing Stainmoor, had previously issued through the Tees valley and formed the eastern arm of the Purple Clay. This western arm of the Purple-Clay moraine having been brought by ice which terminated in the sea that entered the Lower-Trent system as the ice of the Chalky Clay deserted this, it would at its seaward extremity rest on or intermingle with the gravel *e*. The eastern arm of the Purple-Clay ice terminated in the sea which had covered the Basement Clay of Holderness from the time when, in consequence of the changing inclination and increasing submergence during Stage II., the land-ice had deserted this part to issue seawards along the west of the Wold; but it did not, I think, come into existence as a separate body of ice, and reach Holderness until after the Chalky Clay had made some progress.

By the continued rise of the land during Stage III. the interception of the Atlantic vapours, in the form of snow, by the Pennine and by the Westmoreland mountains increased, and with it the volume of the land-ice. This, flowing from these mountains, at length became more than could escape down the valleys of the Lune and Eden, which were its only avenues between these mountains and the Pennine, so that it rose above the level of the Pennine water parting at Stainmoor (in south-east of Sheet 102) and flowed over it, bringing with it the Shap blocks from the western slope. The ice which produced the Chalky Clay, originating wholly on the Pennine and flowing southwards between the Pennine and the Wold, received no erratics from the western slope, such as the Shap blocks, which this altered flow in mounting the watershed brought with it; but flowing down the eastern slope of the Pennine as far as its southern extremity, and extending in the north higher than the submergence had done (though descending to a lower level towards Sheet 63), it destroyed the gravels which during Stage II. had been deposited on this side. The increase of the ice from the Westmoreland mountains may alone have been the cause of this transit at Stainmoor; but as the ice of the Hessle Clay, which I shall examine in the second part of this memoir (and which I now think is as much the moraine of land-ice as is the Chalky Clay, and not, as I at one time supposed, a formation due to coast-ice), took quite a different direction from that which the ice of the Chalky Clay did, and sought the sea nearly in the position it occupies at the present day, in consequence of the present inclination of the land having then been attained, it is possible that the transit may, in some degree, have been due to this recovery having begun with the Purple Clay.

As the ice thus crossing the Pennine issued through the Tees valley, it augmented the flow which had gone in that direction during the earlier part of the Chalky Clay, so that this reached the north-east of Lincolnshire, coming southwards with a westerly inclination, so as to cause it to hug the eastern side of the Chalk wold. In the east of Yorkshire, below the level I have mentioned, at any rate, there was at this time the sea, and here the morainic material became modified by its submarine extrusion; so that, besides the presence of lenticular beds of gravel intercalated in it, its character resembles that of the Lower Clay of Lancashire in containing shell-fragments, proving, in my opinion, that it accumulated beneath the sea in such a way as to form its bottom, and not, like the Chalky Clay, by the sliding into the sea of a mudbank which preceded and was immediately followed by the ice. Coming thus south, it passed over low ground forming the trough between the Eastern Moorlands and the Wold, which it blocked up in the east by a thick mass of the Purple Clay, so that the drainage flows from the coast west round the north and west of the Wold into the Humber. This trough, where not thus blocked up, forms the Vale of Pickering, and the Purple Clay does not further enter it; consequently it is generally overspread with the gravel that had formed there under water during the later part of Stage II. and during so much of Stage III. as elapsed before it was blocked up. Where the Purple Clay crossed the eastern end of this trough, and has thus blocked it up, the Filey cliffs show it very distinctly underlain by a Basement Clay which is sharply separated from it, and which seems to be coeval with the Basement Clay of Holderness formed early in Stage II.; but whether this extends westwards through the Pickering trough under the gravel, I do not know. Having crossed this part while it was below the sea-level, and so not destroyed the Basement Clay for the reasons I have assigned for the similar escape of the Basement Clay of Holderness, it mounted the Wold scarp subaerially for the narrow space in which this is covered by the clay (and beyond it to the eastward, where the sea is now), and, descending again, covered the low ground of Holderness that was still submerged, forming the sea-bottom with its moraine. It was the mountain mass of the Eastern Moorlands which, so soon as the decay of the ice of the Chalky Clay gave room for it, or, more strictly perhaps, while this ice still subsisted in the north, parted the stream coming over Stainmoor, and caused that branch to go off to which the clay between the Pennine and the Yorkshire Wold, which ranges through Sheets 96, 93, and 87 into the north of 82, was due.

It seems at first glance paradoxical to suppose, as I do, that the absence of these gravels on the Eastern Pennine slope in Sheets 82 and 86 should be due to the Chalky-Clay ice having passed along there, while the presence of drift on the same slope to the north of this should be due to the passing over that portion of the ice of the Purple Clay; but it must be remembered that, by being fed from the western slope, this latter brought much débris to the eastern; whereas the former, having its source on the watershed only, could only collect from the first slope it passed down, and carry this to more distant parts; just as we see, by the great vacant space which is shown in Map No. 1 to exist in the midst of the Chalky-Clay formation in Sheets 51, 66, and adjoining thereto, as well as in the Sheets north and north-west of 70 and 83, it has done even in the lower grounds. As the beds succeeding the Purple Clay in Holderness are, as before observed, of fluvio-marine aspect, and at Hessle are underlain by a ripple-marked pan, which is again underlain by a breccia containing mammalian remains, it is clear that these beds were preceded by a complete emergence of this part of England. It is therefore probable that before the formation of the Purple Clay ceased it became in Holderness altogether of terrestrial accumulation*, and that the upper portion of it possesses the chalkless character, because the Wold to the north had, before the accumulation of this later part, become covered with, and protected from degradation by, a cushion of moraine which is itself chalkless by having come from the area north of the Wold.

Although from the destruction, denudation, and disturbance which it has undergone, and its consequent connexion with the case to be presented in the second part of this memoir, I defer all description of the gravel shown in figure VI. by the letter *f* to that part, yet it appears to me that as the rise had proceeded to the extent of some 70 feet only from the disappearance of the Chalky-Clay ice when this gravel began to emerge, and the phenomena connected with the recovery from the westerly depression in the Thames valley do not become conspicuous until after this, the gravel *f* is most probably synchronous with this latest and chalkless part of the Purple Clay, and so of Glacial age.

I have not attempted to show on Map 1 the Lower Boulder-clay of the North-west. Lying west of the Pennine, that clay does not appear to reach further south than Sheet 81, though it stretches westwards from that sheet into North Wales. This formation, as it contains, like the Purple Clay, the shells and shell-fragments of marine Mollusca mixed up with it, has, I consider, had its origin by submarine extrusion, in a similar way; but the species to which these remains in the North-west belong are all of the Moel-Tryfaen type†; and of the two extinct and one North-American species of Bridlington not a trace has been detected. Seeing that at the commencement of Stage II. the sea was confined to the east, and that neither the centre nor the west of England had become submerged, it is entirely consistent with the case which I have been presenting that these should be absent; and the only question to my mind besetting this part of the case is how far the clay of the North-west, except any part of it which may be terrestrial‡, is synchronous with the Chalky or with the latest bed of Stage II., *b 3*.

When we see how all the earlier formed Chalky Clay and all beds of Stage II. which lay in the path of the ice have been destroyed, and reconstructed as new moraine, and carried outward in

* I do not, however, regard the patches of mud with freshwater shells described by Mr. Lamplugh in Geol. Mag. for September, 1879, as occurring in the lower part of the Purple Clay at Bridlington as in any way connected with land conditions where these occur. They are, in my opinion, of similar origin to the patches in the pebbly sands of the Cromer Cliff on which Mr. Reid has founded a division of those sands; that is to say, they are scraps of freshwater deposits brought by ice from other localities, just as was the sheet of peat which in Stage II. I found interbedded in *b 2* at Cromer; and the way which Mr. Lamplugh describes these as tilted, cut up into shreds, and separated from each other by thick walls of Boulder-clay containing marine shells, one of them being, he observes, "*to all intents and purposes a boulder itself*," clearly shows this.

† For list see Reade in Quart. Journ. Geol. Soc. vol. xxx. p. 27; Shone in vol. xxxiv. p. 134.

‡ As to which see p. 478 and bed *b* of fig. XVII. p. 490.

the direction of the sea at the time, we can hardly doubt that something similar must have taken place with any morainic clay which formed on the west of the Pennine, unless the deeper-water conditions there prevailing checked the process. The Lower Clay there, being apparently an uninterrupted formation, must also represent the Purple Clay of Yorkshire, quite as much as it does the Chalky Clay. From the circumstance of the sea of the period towards which the Chalky-Clay moraine moved having lain over the centre and south of England, this moraine now lies over the Eastern and North Midland counties; but it seems to me that the contemporaneous moraine of the North-west, or most of it, must have been carried out so as now to lie in the St. George's Channel and that the Lower Clay of Cumberland, Lancashire, and Cheshire with shells corresponds with that part of the Purple Clay which lies in Sheets 87, 93, 96, and 99 rather than with the Chalky Clay. So far as I have been able to gather the facts, this clay does not underlie the gravel at highest elevations which contains shells, such as the patch near the "Setter Dog," Macclesfield; and it appears to me that these elevated patches are those which have escaped destruction by the ice, from this during its advance not having reached them. This, it seems to me, may have been due to the trend of the southern extremity of the Pennine being easterly, while the inclination of England was westerly, and *on the western side northerly also*; so that a westerly and north-westerly motion of the ice giving rise to this clay prevailed, thus causing it, after leaving its chief gathering-ground in the Westmoreland mountains, to pass the southern extremity of the Pennine at levels below those up to which the sea depositing the gravels of Stage II. had reached; for the position of the Chalky Clay skirting Charnwood Forest in Sheet 63 shows that even on the east of the Pennine the ice as it got southwards reached no great height. Wherever, then, the ice went the gravels anterior to it not saved by the mud-bank were destroyed; and hence such gravels as do occur in the north-west over the clay are altogether later than those at extreme elevations, and separated in age from them by the time involved in the accumulation of that clay.

The highest point to which I have met with notices of gravel containing shells resting on this clay is at Macclesfield Cemetery, which is stated to be 600 feet below the patch with shells at the Setter Dog Inn mentioned in Stage II.* This is later than that (*e*) which I have traced as occurring over the Chalky Clay along the issue of that clay to the sea for the following reasons, viz.:—The line of gravel *e* I have traced as marking a rise of about 300 feet, which had taken place between the time when the gravels formed at the culmination of submergence were deposited and that when the ice of the Chalky Clay began to disappear; but the difference in elevation between these two beds of gravel at Macclesfield is much more than this. Since, however, the Lower Clay of the north-west on which the least elevated of these beds rests represents the Purple Clay also, during the formation of the later portion of which I have just endeavoured to show East Yorkshire completely emerged, this additional difference represents the further emergence during the time in which the Purple Clay

* Darbishire, in Geol. Mag. vol. ii. pp. 41 and 292.

accumulated. This accumulation having been put an end to only by the passing away of the Glacial period (for with these clays do I define the close of the Glacial period, referring the ice-extension of the Hessle Clay to a brief return of extreme cold during the Post-glacial), the sea deposited gravel over the clay which the ice had deserted up to that level to which the emergence at this time had reduced it. The cemetery sand and gravel is therefore synchronous with the gravel *f*, which I have already described as synchronous with the latest part of the Purple Clay rather than with *e*; and where at lower elevations it is overlain by the Upper Clay of the north-west, so as to become the Middle Sand, it is synchronous with beds still later. From Cheshire, where the Lower Clay of the north-west is thus overlain, to the edge of the Chalky Clay in Sheet 62 there is a large interval where sand and gravel only occur; and here, from there having been no intrusion of moraine, the sand and gravel series is uninterrupted, just as it is in the southern part of fig. VI., in the eastern part of fig. VII., in the Surrey and Hampshire areas illustrated by figs. III. & V., and in the Chiltern, Marlborough, and Cotteswold districts.

As I shall describe in the second part of this memoir, marine conditions prevailed uninterruptedly on the western side of the Pennine until the Upper Clay of that region emerged; for in this clay, at low levels, marine shells occur, and no denudation of the Lower Clay into the form of hill and valley therefore took place in the interim, such as occurred between the Purple Clay and the Hessle beds in Holderness; in consequence of which the Middle Sand and Upper Boulder-clay rest upon the Lower in such a way in the north-west as make the two clays difficult of distinction there. This feature has induced some geologists to insist that there is no distinction between the Upper and Lower Clay of Lancashire, and that they and the Middle Sands of that region are all one formation, as in the sense I have mentioned of uninterrupted marine conditions being maintained they are. On the east side of the Pennine, in Holderness at least, this is different, for the Hessle sand and gravel, which is the equivalent of the middle sand of Lancashire, is, where fossiliferous at all, fluvio-marine, and rests at Hessle on a land-surface; and it occupies along the coast-section valleys eroded in the Purple Clay, which sometimes, as at Dimlington, are cut quite through this and down into the Basement Clay beneath it, while the Hessle Clay, which overlies this and is coeval with the Upper Clay of the north-west, has yielded no trace of shells.

Thus, so far as I have been able to trace them, the whole train of facts, perplexing as they have long been to me, now appear to me harmonious. As regards the phenomena presented by Wales, I know too little of them to say more than this, viz. that the gravels at high elevations accumulated there during the culmination of Stage II., of which the patch at 1350 feet on Moel Tryfaen is a remnant, appear to me to have been mostly destroyed by the ice which during the rise increased over Snowdon, as it did on the Pennine and Westmoreland mountains; but Snowdon being an isolated mountain mass and not flanked, as are the Westmoreland mountains, by the continuous rampart of the Pennine, no such accumulation of ice took place there as that which, meeting with resistance in its escape down the valley of the Eden and the Lune, mounted the Pennine watershed at Stainmoor. Hence the ice which resulted from the snows which Snowdon intercepted, passing more freely down it and through the valleys which furrow its sides, avoided some of those shoulders of the mountain mass on which these gravels had accumulated, such as Moel Tryfaen, and there, and there only, are they preserved.

Throughout the long period which is embraced in this part of my memoir, nothing presents itself which to my apprehension indicates any oscillation of climate whatever. The increase of cold from the commencement of the Red Crag to the advance of the ice into the sea of that Crag extended as I have shown it at the outset of Stage II., and before the change in inclination and consequent submergence of all England took place, appears to have been uninterrupted, while its recession from that position was merely the consequence of that change of inclination and great submergence. As to the epoch when the maximum of cold was attained, this, for aught I can see to the contrary, may have been attained during the formation of the Cromer Till and remained unaltered up to the close of the Chalky Clay, decreasing thence to the close of the Glacial period; and we must not confound the maximum of glaciation with the maximum of cold. The shrinkage of the ice of the Chalky Clay does at first sight seem to indicate the intercalation of a warmer climate; but on examination such an explanation seems unnecessary. It occurred to me that this shrinkage might have been due to the transit of the ice over the Pennine watershed at Stainmoor, which so far interfered with the ice of the Chalky Clay as to cause this to diminish, and thus give rise to the phenomena which I have described in that respect; but on reflection I do not see that this could have been the case; and the shrinkage must, I think, have been due to a different cause. As the shrinkage began in East Anglia when some 80 feet of the total rise which took place during the accumulation of the Chalky Clay remained to be accomplished, it was probably due to the effect which emergence produced on this shallowest part of the submerged area, by pushing the North Sea so much further off; for where the sea was deeper, and so remained in greater contiguity to the Pennine throughout the Chalky Clay, as was the case in Sheets 53, 62, and 63, the shrinkage appears, from the coincidence in level between the gravels *c* and *e*, not to have occurred until the close of the formation. The eventual retreat of the ice of the Chalky Clay can therefore, I think, have been due only to a diminution in the supply from amelioration of climate; for which reason the western arm of the ice of the Purple Clay (which was a remnant of the ice of the Chalky Clay, reinforced by a branch from that which, crossing Stainmoor and issuing through the Tees valley, had given rise to the coast-belt of Purple Clay) reached no further than the north of Sheet 82.

Whether vegetation adequate to the support of great Mammalia, whose remains occur in the Hoxne brickearth and other deposits accumulated towards the end of Stage III., sprang up on the moraine as it became thus uncovered many will probably doubt. In my view, however, this was the case; as it also is that the Hippopotamus lived in Europe during the time of frozen rivers and throughout the year, the habits of the existing African species no more indicating the habits of the European newer Pliocene species than the habits of the ice-bear indicate those of all those other species of bear which are closely allied to it; but this, however, together with the evidences of a brief though great recurrence of cold during the period embraced within the second portion of this memoir (which I still continue to regard as correctly defined under the term "Post-glacial"), and which recurrence culminated during the accumulation of the gravel *g*, and of its synchronous formations, the Hessle Clay, the Upper Clay of the North-west, and the marine gravel of the Sussex low levels with blocks of hypersthene rock, I shall examine in that portion.

Note as to Map 2 in Plate XXI.

From the difficulty in ascertaining elevations with sufficient exactness, I have probably omitted some small islands in the south of Sheet 63. Of these one is that of Saddington, mentioned at p. 510, which lies immediately north of the island shown in the south-east of this sheet; while others may be formed by the water-partings between the tributaries of the Soar, and those of the Swift and Welland; but they are of minute dimensions, most of this sheet having, from the westerly increment of submergence, been sea. The two small islands in the south of Sheet 7 should have been omitted. In the south of Sheet 47 the river-valleys were, at the stage of emergence shown by the map, fiords, divided from each other by islands or peninsulas of Lower Tertiary and Chalk, in the same way that the river-valleys of Sheets 50 and 56 were probably fiords, divided from each other by peninsulas or islands formed of the beds of series *a* and *b*, nearly all now concealed by the covering of *d*. In these fiords the gravel *c* accumulated; but the peninsulas, in consequence of the smallness of the scale, have not been prolonged to their proper extent. They had been submerged during Stage II., and some thin remains of gravel resting on London Clay corresponding to *b'*, or the higher part of *c*, occur on one of them to the south of Braintree, where a small break in the pall of *d* exposes that clay. As the elevation of the parts shown in outline in Sheets 62 and 64 includes the Chalky Clay, and this lies thick there, they were probably shoals rather than islands when first covered by the ice. The partially destroyed junction of *c* with *d* at Graffham, mentioned at p. 485, was on this outline. The continuation of this map south of the Thames I have reserved for the second part of this memoir.

Discussion.

The President spoke of the great value of the labours of Mr. Wood, carried on during so many years and with such indefatigable energy.

Mr. Whitaker stated that the paper was most interesting as containing an epitome of Mr. Wood's views. He thought too much importance was attached to the Red Crag, which probably represented only a very insignificant period of time. He remarked on the changes in the East-Anglian sections resulting from the wasting-back of the coast. Some of the geological surveyors were inclined to regard the Hoxne brick-earth as older than the Boulder-clay, while others considered it younger than that formation. In the neighbourhood of Brandon laminated clay is found under Boulder-clay; but there is more than one laminated brick-earth in the country. No man in England had worked at these beds more steadily and industriously than Mr. Wood, and no one was more ready to communicate his accumulated facts to other geologists. His opinions on the beds in question were entitled to the highest consideration.

Prof. Hughes gave expression to the general feeling of sympathy in the Society with Mr. Wood in his serious ill-health. He regarded the quartz-pebble gravel of the highest plateau of East Anglia as older than any of the Boulder-clay of that area. He did not agree with Mr. Wood that the cannon-shot gravel might be formed by the *débâcles* from melting ice, nor did he think that the Moel-Tryfaen beds are of the age assigned to them by the author. He regarded the oscillations of level in Post-pliocene times as being of a local character, and not of the widespread kind suggested by Mr. Wood.

Prof. Seeley said that the views of ancient physical geology enunciated by Mr. S. Wood were of very great interest. He especially referred to his views on the mode of excavation of valleys by estuaries rather than by the existing rivers in those valleys. He agreed with Prof. Hughes as to the correlation of the drifts on the east and west of England. He did not think these facts, however, affected the truth of Mr. Searles Wood's views. He supported the view that the plateau-gravels are of marine origin.

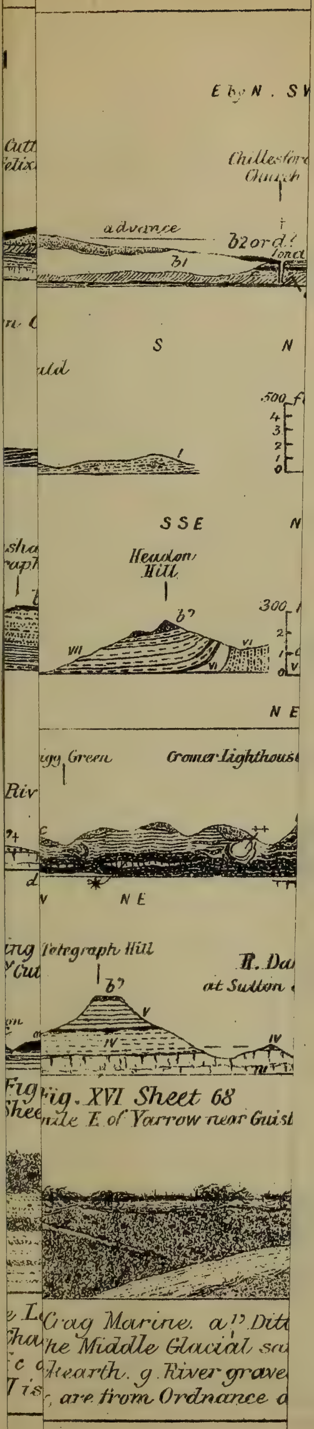
Mr. De Rance said that sands and gravels at Blackpool at low elevations contain the same shells as those at high levels at Macclesfield; and he regarded all the deposits as formed on a subsiding area, the sands and gravels creeping up the hill-sides from the lowest to the higher levels. The sands and gravels are more persistent at different levels than are either the Upper or Lower Boulder-clay. He could not regard the finely stratified Boulder-clay of Midland and North-western England as being formed in any way by land-ice. The valley of the Ribble cuts its way right through all the glacial deposits, while valley-gravels lie upon all of them, alluvium and peat lying at the bottom of the valley.

Mr. Charlesworth spoke of the great readiness of the author to assist those working in the same field. He quite agreed with him in his views concerning the Red Crag.

Mr. Jukes-Browne supported Mr. De Rance in the view that the Chalky Boulder-clay was not formed by land-ice. He also thought that the author was mistaken in supposing that there was any evidence of erosion between the Lower and Mid Glacial in the Cromer section.

Prof. Judd expressed his sympathy with the author in the illness which prevented his presence at the Meeting. He thought that the existence of great transported blocks, like those of Ponton cutting and the neighbourhood, could scarcely be accounted for by any land-ice theory of the formation of the Chalky Boulder-clay.

The President also expressed regret at the absence of the author, who had done such valuable work in a most difficult field of research.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earth. g. River grave
, are from Ordnance

Reference to the Figures. I The Neocomian. II The Gault & Upper Greensand. III The Chalk. III' Chalk glaciated. IV Thanet & Woolwich Beds. V The London Clay. VI The Bagshot series. VII The Lower Oligocene. VIII Pebble beds (Diestian ?). Newer Pliocene series a to g, viz! a' The Red Crag Marine. a'' Ditto Fluvio-Marine. a² The Chillesford Clay. b' The Bure Valley sand & shingle. b² The Cromer Till. * (in fig. VIII) Sheets of Chalk interstratified therein. b³ The Contorted Drift. ++ Masses of marl or reconstructed Chalk therein. + Masses of Gravel therein. b' Sand & Gravel at the time of greatest submergence. b (in fig XVII) is Clay with striated blocks. c The Middle Glacial sand & gravel. This in fig VIII is partially eroded with b' of the other figures. x Seam of molluscan remains in c. d The Chalky Clay. In fig. X. d' are bands of Chalk silt, & c' pockets of c in d. e Continuation of c after the disappearance of the land-ice. e' Gravel & Sand of the ice melting. f Marine sand & Gravel of the Thames Valley. f'' Cyrena brickearth. g River gravel. — Alluvium. † Sections open. Figs. I, I' III, V, VI, VII, & VIII are on the horizontal scale of half an Inch & fig. IX of two inches to the mile. The other figures are on the true scale. N.B. The folding of V in fig VII is greater & sharper than shewn, & IV & III should appear above the datum line in the centre of the figure. The Elevations of Figs. I to IX only are from Ordnance datum.

36. *On the* Old Red Sandstone *of the* North *of* Ireland *. By Joseph Nolan, Esq., M.R.I.A., of H.M. Geological Survey of Ireland. (Read June 23, 1880.)

(Communicated by Professor Hull, LL.D., F.R.S., F.G.S.)

In the North of Ireland there are two distinct kinds of rock, classed both on Griffith's and Portlock's Geological Maps as Old Red Sandstone†. The lower and larger member of this group occupies a considerable area, having an extent of about thirty miles in length by an average width of ten miles, from Lough Erne north-eastwards to Pomeroy in Tyrone. It consists for the most part of dark red and purple conglomerates, often coarse and massive, and of purple, and sometimes, though rarely, greenish-grey, pebbly and fine-grained sandstones, often micaceous and in some cases calcareous, with sandy shales. The pebbles in the conglomerate, which vary from the smallest size up to blocks over a foot in diameter, consist of purple felstone, grits, schist, and quartzite. Of all these the felstone pebbles are by far in greatest proportion, the rock being in some places almost entirely composed of them; and their source is unquestionably certain tracts of igneous rock which will be presently described.

On the north and north-west these conglomerates, sandstones, &c. are bounded by metamorphic rocks, from which they are separated by a fault; but in the north-east, near Pomeroy, they rest unconformably upon fossiliferous slates and grits of Lower Silurian age. Though the discordance between these formations is not actually seen in section, yet there can be no doubt of its existence, the southern extension of the Lower Silurian rocks occupying a semicircular area, in which the strike is east and west, while the red sandstones that margin it on the west, south, and east strike respectively to the N.W., E. and W., and N.E., thus proving their deposition around what appears to have been a low-lying cape or projecting point of the ancient Cambro-Silurian land.

Associated with these red sandstones and conglomerates are several tracts of igneous rock, which appear to have been submarine lavas, poured out at various periods during the formation of the conglomerate, the greater part of the pebbles in which, as before remarked, are evidently derived from them. They are basic felstones of a purple colour and in general an earthy aspect, seldom exhibiting any crystalline structure, but compact, with vesicles in many places, and occasionally crystals of felspar and prisms of hornblende. Thus it may be seen that the rock answers very closely to Cotta's

* This paper is published with the permission of the Director-General of the Geological Survey.

† It is right to mention that in a note on Griffith's map it is stated that the lower of these divisions "may possibly belong to the Silurian system."

definition of Porphyrite—a name which, however objectionable, it may be well to employ, as serving to identify this rock with others that may occur under similar circumstances.

In some places the tops of these felstones are tuffoid, though no well-marked beds or large deposits of such ejecta occur, this being probably due to the subaqueous conditions under which the mass was ejected, so that fragmentary accompaniments would be drifted away by tides and currents, often forming deposits in other places, as mentioned by Scrope in his work on Volcanos, p. 247.

Besides these basic felstones there are other varieties of igneous rocks associated with the sandstones. These are generally melaphyres, often extremely vesicular, the cavities being in time filled with white and pink calcite, giving the rock a peculiar spotted appearance, which few persons who have traversed the district east of Omagh, where it is extensively used for road metal, can fail to have noticed. The principal source of these is at Recarson, some three miles east of Omagh. Here every change in texture and colour is visible; at one part the rock is blue and compact, at another vesicular, with calcite, while at the principal quarry it is mostly of a purple colour, and crystalline with glistening facets of a rich bronze-coloured mineral that seems to be augite. As its relations to the surrounding rocks are obscure, it could not be determined whether it was contemporaneous or intrusive; the vesicular condition of much of the rock might lead us to infer the former; yet if so, it is strange that no fragments of it occur in the surrounding sedimentary rocks, as is the case in those overlying the contemporaneous felstones.

Besides these trappean rocks there are masses of granite associated with the sandstones. These, as I have already shown elsewhere*, are intrusive through the lowest beds of this series, vitrifying the sandstones in contact and converting them into quartzites. It was also shown that the intrusion took place prior to the deposition of the upper red quartzose conglomerate (Lower Carboniferous, so-called), as in some places the basal beds of that formation are almost altogether composed of its *débris*, a circumstance which, taken in connexion with others presently to be mentioned, is a proof of the great length of time which must have elapsed between these formations.

Red Quartzose Conglomerates and Sandstones (*Lower Carboniferous so-called*).—These consist of conglomerates, distinguished by the prevalence of white and pink quartz pebbles in a reddish-brown base, purple, reddish-brown, and grey sandstones generally micaceous, and sandy shales, passing upwards into yellow and white pebbly sandstones and grits. The basal beds are often very coarse, and in many places so much resemble those of the lower system, that the discrimination between them is often a matter of considerable difficulty. Although in some sections these rocks rest with apparent

* See G. S. Memoir to accompany Sheet 34, and a paper "On the Metamorphic and Intrusive Rocks of Tyrone," Geol. Mag. vol. vi. no. 178.

conformability upon those of the older series, yet in most places they are distinctly, and often widely unconformable. I have endeavoured to account for this discordance, in my description of the district *, by the absence of a considerable thickness of rocks representing the Upper Old Red Sandstone, the lower series being considered to be Lower Old Red Sandstone, and the upper the basal beds of the Carboniferous system. I was the more inclined to adopt this view from the remarkable resemblance in so many points of the lower series of conglomerates &c. to those classed as Lower Old Red Sandstone in Scotland (a resemblance which Professor Ramsay also mentions in the preface to the memoir just referred to), and from the similarity of the quartzose conglomerate series to many others in various parts of Ireland, which, though formerly considered to be Old Red Sandstone, have for many years past been classed in the Carboniferous system.

In Scotland, as mentioned in the very able monograph on the Old Red Sandstone by Dr. Geikie, discordance exists, which Sir R. Murchison accounted for by the absence of a group of rocks representing a Middle Old Red Sandstone period, a view in which Dr. Geikie does not concur †.

Some time ago Mr. Kinahan drew attention to the similarity in geological position of the lower conglomerates of Tyrone (Fintona beds) to that very remarkable group of rocks in the south-west of Ireland called the Dingle beds, which, resting conformably upon Upper Silurian rocks, are overlain unconformably by conglomerates and sandstones, which have always been regarded as the true Old Red Sandstone. The sequence upwards from the Silurian rocks could not be proved in Tyrone; but it became an important matter to settle definitively if possible the position of the upper conglomerates. If these were found to be identical with those called Old Red Sandstone in the south of Ireland, Mr. Kinahan's view must be held to be correct in relegating what has been called the Lower Old Red Sandstone of Tyrone to the horizon of the Dingle beds. During a short tour which, owing to the kindness of Professor Hull, I was permitted to take through the south of Ireland last summer, I had opportunities of seeing many sections through the Old Red Sandstone of that district. At Waterford the basal beds of that formation were seen resting almost horizontally on vertical slates of Lower Silurian age, forming a very striking feature in the cliffs over the railway-station; they are massive quartzose conglomerates of a dark purple to reddish-brown colour, the contained pebbles being almost exclusively of white and pink quartz and quartzite, perfectly identical with the upper (the so-called Carboniferous) conglomerates of Tyrone. In the valley of the Blackwater at Lismore the upper parts of the series were seen, and consist of massive grey and purple sandstone, closely resembling certain beds in the " Car-

* See G. S. Memoir just quoted.

† Professor Hull believes that the absent beds are the Marine Devonians (Lower and Middle).

boniferous Sandstone" tract west of Draperstown, Co. Derry; these are succeeded by purple fine-grained and sometimes cleaved sandstones, the highest beds being greenish-grey and olive-coloured grits, which are classed as the upper part of the Old Red Sandstone (Kiltorcan beds), but for which I do not know any representatives in the North of Ireland. Lastly, these are followed by a thin band of Limestone shale and Lower Limestone, forming the massive crags on which the castle of Lismore is romantically situated.

Similar observations were made at the Galtees, and the western prolongation of that range called the Ballyhoura mountains. In a section at the latter, some four miles north of Buttevant, Co. Cork, the highest beds seen were reddish to light purple fine-grained sandstones and clay rocks, alternating with yellowish grit and shale, which are regarded as the upper part of the Old Red Sandstone; while the lower division consists of micaceous purple sandstones and shales over coarse yellowish-white and reddish-brown pebbly sandstones and quartzose conglomerates, of the same kind, though not so massive, as those in the basal beds of the formation at Waterford. On the flanks of the Galtees near Kilbeheny similar facts were observed, reddish-brown to purple sandstones and sandy shales alternating with quartzose pebble-beds and conglomerates.

On the whole, therefore, I found the closest resemblance in lithological character between these typical Old Red Sandstones of the south of Ireland and those which in the north and other parts of Ireland have been called Carboniferous—a point which is well worthy of observation, as formations perfectly identical thus come to be placed on different geological horizons. Unfortunately no fossils have been found which would serve for comparison, except in the Upper Old Red Sandstone, where the remarkable freshwater fauna and plant-remains of Kiltorcan occur, which have been so well described by Mr. Baily. This formation, however, is, as before remarked, not known in the North of Ireland.

Turning now to the sandstone district which it is particularly intended to describe in this paper, we find in Tyrone, that the upper or quartzose conglomerates (so-called Carboniferous sandstones) are succeeded by the Carboniferous Limestone; but as they are traced further north into County Derry, a considerable thickness of sandstone and other beds come in between them and the limestone. These intermediate rocks attain a great development at Dungiven and about Draperstown. At the stream called the White Water, in the latter locality, an excellent section is exposed. The underlying or "Lower Carboniferous" series consists of the usual quartzose conglomerates, coarse purple sandstones, and sandy shales, also a remarkable rock mostly composed of reddish-brown and purple grit pebbles, apparently derived from the Fintona series, closely resembling some of the basal beds that overlie the latter in the district south of Pomeroy, Co. Tyrone. Over these is the series of sandstones referred to; the lowest beds are yellowish-grey and massive grits with pebbles, red to purplish sandstones, thin shales, and quartzose calcareous pebbly beds; higher up are hard green grits and bluish shales, remarkable quartz pebble-beds highly calcareous, dark shales full of remains of *Modiola MacAdami* *, and thin arenaceous limestones, the surfaces of which are curiously cut up with cross systems of joints, apparently due to rapid desiccation. Higher up no rocks are met with for a quarter of a mile, where what seem to be the same series reappear and continue to the boundary of the metamorphic rocks, from which they are separated by a fault. In the district to the east, however, there is sufficient evidence that they underlie the Lower Limestone.

All these rocks are cut up by numerous small faults, which, indeed, seem characteristic of this series, being also observed at Altmover Glen, Dungiven, and wherever similar rocks are exposed. Most of the sections in this neighbourhood have been described with considerable minuteness by General Portlock, in his Geological Report on Londonderry, &c.

In most localities there is a prevalence of soft yellow sandstone and sandy shale with calcareous sandstones and impure limestones, often magnesian, chiefly near the junction with the underlying conglomerates. Fossils, though rare, were found in several places, as at the Hass, Dungiven, where there are plant-remains and also scales of *Holoptychius Portlocki*, Ag., and at another locality one and a half mile N.E. of this, where fragments of *Calamites* were found. In Altmover Glen similar plants occur, with others which Portlock doubtfully refers to *Pecopteris*; here also are shells which he believes to be *Producti*. There is therefore no doubt that this series of sandstones &c. should be classed with the Carboniferous system; and I think the whole facts of the case show that they should be considered the representatives in time of the Coomhola grits and Carboniferous slate of the south of Ireland, and the Calciferous Sandstone of Scotland, which Jukes regarded as the equivalent of these formations. The following table shows the correlation of these rocks with those in the south of Ireland and in Scotland:—

North of Ireland.	South of Ireland.	Scotland.
5. Lower Limestone.	Lower Limestone.	Lower Limestone.
4. Yellow, white, red, and grey sandstone, often calcareous, in some places pebbly, with thin bands of impure limestone or dolomite and dark shales with *Modiolæ* &c. (White Water and Dungiven beds.)	Carboniferous slate and Coomhola grits.	Calciferous Sandstone series.

* Portlock also found the following fossils in these beds:—*Posidonomya complanata* (locally abundant), *Dithyrocaris Colei*, *D. orbicularis*, *Cephalaspis?* (fragment of).

3. Not recognized.	Upper Old Red Sandstone (Kiltorcan beds).	Upper Old Red Sandstone.
2. Coarse yellow sandstone and pebble-beds, passing downwards into pink, reddish-brown, and purple sandstones and conglomerates full of white and pink quartz pebbles.	Old Red Sandstone of the Galtees, Waterford, &c. "Old Red Sandstone proper" (Jukes).	
UNCONFORMABILITY.	UNCONFORMABILITY.	UNCONFORMABILITY.
1. Purple micaceous sandstones and coarse conglomerates, with felstone (porphyrite) pebbles and contemporaneous volcanic rocks (Fintona beds).	Dingle beds and Glengariff grits.	Lower Old Red Sandstone.

Should the Old Red Sandstone be considered a distinct formation from the Carboniferous?—As this latter formation appears to be everywhere conformable to the former, we may be inclined to regard the Old Red Sandstone rather as the base of the Carboniferous system than as a separate and distinct one; yet the circumstances under which they were formed must have been very different—the one being a marine, the other a freshwater deposit. The great lakes in which the Old Red Sandstone seems to have been formed probably gave place gradually to lagoons, and ultimately became merged in the sea wherein the Carboniferous strata were subsequently accumulated. The direction of the depression seems to have been northwards, for the greatest masses of Old Red Sandstone occur in the south, principally in the counties of Cork and Waterford; they are also largely spread around the Silurian rocks composing the hills that extend semicircularly from the vicinity of Lough Derg to the Slieve-Bloom range. Little of it is seen on the east, the older rocks there forming low ground; to the west and north masses of considerable extent, though of far inferior area to those in the south, appear to have fringed the ancient shores of the metamorphic and Silurian rocks that make up the highlands in these districts; while in the central parts little occurs, except where, through faults or subsequent folding and undulation of the strata, portions reappear in the midst of the great limestone plain.

The persistence of a very remarkable lithological character is also well worthy of observation, for in few places is the rock composed of any local *débris*, but, on the contrary, is generally totally different, being derived from some source apparently unknown—a fact which, taken in connexion with the wide area over which it is found, is suggestive of the original great extent of the deposit. That this merely represents the area of the ancient lakes is by no means probable, but rather the greater part of the floor of the Carboniferous sea. As depression continued, limestones would be formed in the deeper waters, while near the land sandstones, shales, &c. would be deposited, in this way giving rise to the great thickness of those rocks which, in the south of Ireland particularly, is interposed between the quartzose conglomerate and the limestone proper. Such deposits, too, might be expected occasionally to partake of the character of the basal conglomerates, and a rearranged form of these rocks would often be the result, which explains the occurrence of pebbly quartzose beds like those in the White Water before referred to, and which are almost undistinguishable from the Old Red Sandstone.

In conclusion, I think it would be very desirable to retain the term Old Red Sandstone as applicable to those rocks included under groups 2 and 3, comprising all those above the unconformability at the top of the Fintona and Dingle beds up to the commencement of strata in which marine forms reappear*. Undoubtedly these beds form the base of the Carboniferous group; yet on account of their very great difference, both lithologically and palæontologically, I think it necessary that they should be distinguished from them, and indicated by a different symbol and colour on geological maps. The term Carboniferous Sandstone, often given to portions of this group, has been productive of much misunderstanding and confusion, while Old Red Sandstone, if strictly limited as proposed, would have a fixed and definite application.

* Professor Hull holds similar views regarding this classification. See his paper on the Carboniferous rocks, Quart. Journ. Geol. Soc., Nov. 1877, p. 616.

37. *On a* Second Precambrian Group *in the* Malvern Hills. By C. Callaway, Esq., D.Sc., M.A., F.G.S. (Read May 26, 1880.)

The Herefordshire Beacon, situated a little south of the middle of the Malvern range, sends out towards the east and south-east several buttresses or spurs; they occupy an area of about one mile from north to south and half a mile from east to west. In the summer of 1878 I visited the Malvern Hills to compare the rocks with those of Shropshire, and I was sanguine, from Dr. Holl's description of this district, that I should find in it some equivalents of the younger Precambrian group of that county. In his valuable and thoroughly scientific memoir on the Malvern Hills, published in the Journal of this Society in 1865, Dr. Holl describes the area in question as "occupied by baked rocks * of the probable age of the Hollybush Sandstone and Black Shales," the alteration of the rocks being supposed to be due to immense trap-dykes—a very natural interpretation of the facts when we consider the vague ideas of petrology and of metamorphism which prevailed 15 years ago. On my first visit I had the advantage of Dr. Holl's guidance. I found that he had advanced beyond his original position, and was quite prepared to consider a new reading of the district. I saw at a glance that the rocks were quite of a type with which I had been familiar in Lilleshall Hill, the extreme north-easterly summit of the Salop Precambrian chain. The prevailing variety is a very compact, flinty, hornstone † (note 1, p. 538) of a grey or reddish-grey colour, undistinguishable from the rock forming the craggy boss which crowns the summit of Lilleshall Hill (note 3). I have seen this rock in almost every part of the Malvern mass, from near its junction with the gneissic axis to where the spurs break down abruptly upon the Triassic plain to the east. At the south-east end, overlooking Castle Morton Common, is a greyish felspathic breccia. The contained fragments are similar to the hornstone. Here and there the rock is less compact, and closely resembles some of the indurated ash of Lilleshall Hill. Dr. Holl refers to "an unaltered sandstone" and to some "black and green shale," both near Little Malvern; but I have been unable to detect these rocks, and they are obviously quite subordinate to the hornstones. I could not satisfy myself as to the strike of the beds; but I noticed the "softer and less siliceous" band which intervenes between the hornstone and the ridge, so that it would appear as if the strike were parallel to the gneissic axis, and therefore quite discordant to the strikes of the older series.

That the newer Precambrian rocks of Malvern are to be correlated with the younger of the two Salopian groups, or with a part of it, receives support from the similarity, I might almost say identity, of

* Dr. Holl gives a section showing the position of the "baked rocks," at p. 92.

† I use the term "hornstone" with hesitation. It seems to me that a new term is wanted for these rocks. They hardly correspond to Hälleflinta.

the succession in the two areas. In Shropshire undoubted Malvern gneiss and granitoid rock * lies at the base of the Wrekin volcanic series (of which the Lilleshall beds are a part), and is separated from it by a great interval, during which the lower group was metamorphosed, uplifted, and denuded, the worn fragments forming conglomerates in the younger series. At Malvern the newer group lies against one flank of the gneissic axis, and is clearly separated from it by a great interval of time, since it rests upon the *edges* of the older beds. In Shropshire the felsitic group is immediately overlain by a band of quartzite† which is absent at the Malverns. Then follow alike in both districts the Hollybush Sandstone and the *Dictyonema*-shales. During the Ordovician epoch (Lower Silurian of the Survey) both areas were above water and deposits are wanting. In the May-Hill Sandstone period, depression of both the Malvern and Wrekin chains set in: first, shore-deposits (May-Hill conglomerates) fringed the margin of the sinking islands; and finally marine sediments (Wenlock and Ludlow) entirely covered in the submerged land. In Devonian times reemergence took place, the rising wedges of Precambrian rock in both districts pushed up and sometimes thrust over the Silurian beds, and the old ridges once more became dry land. Submergence, more or less complete, was again resumed in the later part of the Carboniferous epoch, evidenced in both areas by the comparative absence of the Carboniferous Limestone and by the attenuation of the Coal-measures towards the higher summits of the Precambrian land.

In both districts the chief dislocations were also contemporaneous. I first call attention to the post-Triassic (probably post-Cretaceous) dislocations which threw down newer Palæozoic and Mesozoic strata against the Malvern axis on the east, and against the Wrekin axis on the north-west, while, alike in both districts, the same Cambrian and Silurian deposits were left flanking the respective ridges on the opposite side. These post-Triassic faults acted along preexisting lines of dislocation, some of which were formed in Precambrian times, and the movements were simultaneously renewed at intervals in both Shropshire and the Malverns. In both areas the volcanic group is faulted against the gneiss, the Longmynd ‡ rocks against the Precambrian, the Hollybush Sandstone against the Precambrian, the *Dictyonema*-shales against the Hollybush Sandstone, and the Silurian against the Precambrian.

Thus the succession of deposits, the history of the elevations and depressions, the contemporaneity of the main dislocations, and the close lithological resemblances between the respective groups, together with the identity of the relations between the older groups and the flanking formations whose contemporaneity is proved by fossils, furnish us with reasonable evidence of the correlation of the Precambrian rocks of Shropshire with those of Malvern, and in parti-

* Quart. Journ. Geol. Soc. vol. xxxv. p. 652.
† Quart. Journ. Geol. Soc. vol. xxxiv. p. 754.
‡ Longmynd sandstones and grits are seen south of the Malvern axis at Huntley, east of May Hill.

cular of the Lilleshall series with the "baked rocks" of the Herefordshire Beacon.

I may state, though the fact is not of much value as evidence of correlation, that the intrusive doleritic rocks which break up through the Malvern felspathic series can be exactly matched in the Wrekin and Caradoc chains. I refer especially to a dark green rock, with amygdaloids of radiated * epidote, which is common at Caer Caradoc, and to a coarser variety of a lighter colour which is abundant further to the north-east.

Professor Bonney (note 2) identifies as possibly an intrusive quartz-felsite a doubtful-looking rock associated with the Malvern hornstone.

The relations of the two Precambrian formations at Malvern at once suggested to me the sequence at St. David's, and I shortly afterwards hinted the correlation to the Chester Natural-History Society. Great caution must, however, be used in comparing such distant groups. I have long been disposed to consider the felspathic series in Shropshire, or at least the Lilleshall group, as representing the Pebidian. The lithological resemblances to the St.-David's rocks are very close, and the deposits in both areas are due to volcanic action. If the Lilleshall series is Pebidian, then the hornstones at the Herefordshire Beacon are Pebidian. It is also of importance to notice that these "baked rocks" can hardly be distinguished in hand-specimens from some of the St.-David's rocks, especially those which occur at Nun's Well (note 4).

But the correlation of the central ridge at St. David's (Dimetian of Hicks) with the Malvern axial ridge is not so evident. The Malvern series is almost exclusively gneissic, foliation is well marked, and hornblende abounds. In the St.-David's axis gneiss is absent. Having searched the series from top to bottom, with the assistance of Dr. Hicks's sections, I have been unable to detect schist of any kind, the "quartz-schists" originally described being really quartzites and granitoid rocks. On the other side we may set the fact that these granitoid rocks are very similar to the "granite" so largely developed in Swinyard's Hill, the Worcestershire Beacon, and the North Hill. In the present state of our knowledge I cannot venture to express a more definite opinion.

Professor Bonney, F.R.S., has independently observed the Pebidian rocks of Malvern, and he permits me to say that he agrees with me in my general conclusion as to their age. The following microscopic notes are kindly furnished by him:—

"(1) *The prevailing type at the Herefordshire Beacon.*—A rock of sedimentary origin. A ground-mass of very finely granular aspect, composed of earthy matter thickly interspersed with extremely minute microliths, probably of felspar, through which are scattered a few rather larger fragments of felspar, or quartz, or both; some minute epidote is also present. The specimen belongs to a type

* This is probably the "actinolite" of Murchison ('Siluria,' 1867, p. 65, note). I am indebted to Mr. Allport for the identification.

common among indurated rather flinty slates with little cleavage. There are some smaller infiltration-veins of quartz (?).

"(2) *East of the Herefordshire Beacon.*—Belongs to a group of rocks about which it is difficult to be certain. The ground-mass is minutely cryptocrystalline, with small grains of epidote in cracks and irregular clusters, and with numerous scattered grains of quartz and felspar; these are generally rather ragged at the edge and irregular in form. Here and there patches of the ground-mass are more coarsely crystalline. The rock in some respects resembles certain 'porphyroids,' examples of which occur at High Sharpley, Charnwood Forest; but on the whole I think it rather more like a true quartz-felsite, and very likely an intrusive rock.

"(3) *Lilleshall Hill* (quarry on S.W. side, on or near the strike of the summit beds).—One of the indurated slate or Hälle-flinta group; consists apparently of minute granules and perhaps microliths of felspar and fibres of a pale greenish chloritic mineral (showing bright colours with crossing Nicols) with a somewhat parallel arrangement; opacite and ferrite are scattered here and there about the slide. The structure is not unlike that of some of the flinty slates of Charnwood.

"(4) *Nun's Well, St. David's.*—One of the same group, but perhaps a little more altered. The rocks seem to be full of exceptionally small microliths (some, however, may be fine fragments) of quartz, felspar, and perhaps epidote."

Discussion.

Dr. Hicks quite agreed with the author in his conclusions as to the Pebidian age of the beds in question.

Mr. Keeping said that he had been much struck with the resemblance between the Salopian and Malvernian rocks during recent visits to those districts.

38. *On a new* Theriodont Reptile (Cliorhizodon orenburgensis, *Twelvetr.*) *from the* Upper Permian Cupriferous Sandstones *of* Kargalinsk, *near* Orenburg *in* South-eastern Russia. By W. H. Twelvetrees, Esq., F.L.S., F.G.S. (Read April 14, 1880.)

The fossil to be described in this paper was found, in the summer of 1879, in the copper-mine of Roshdestvensk, about thirty miles N. of the town of Orenberg. The mine forms one of several groups known collectively as the mines of Kargalinsk. The steppe in which it is situate is composed of Upper Permian beds of marl and sandstones resting upon limestone containing Zechstein fossils. Copper-mines in this steppe have been worked from time immemorial. Organic remains are only found in the runs of copper-ore and are everywhere absent from the bare sandstones. I have resided several years in the neighbourhood and am acquainted only with the following:—

Calamites
Lepidodendron.
Leaves of *Aroides crassispatha*, Kutorga.
Conifer trunks and twigs.
Unio, sp., allied to *U. umbonatus*, Fischer.
Amblypterus, sp.
Platysomus, sp.
Remains of Labyrinthodonts.
Remains of Saurians undetermined, including *Rhopalodon*, Fischer, and *Deuterosaurus*, Eichwald.

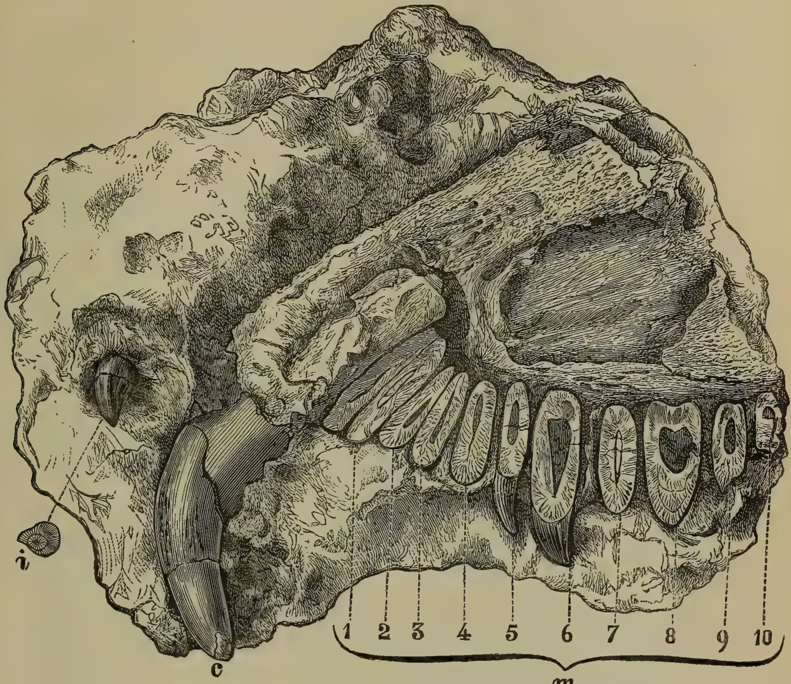
Description.

The fragment under consideration is a portion of a reptilian jaw*, apparently comprising parts of the maxillary and premaxillary bones. When it first came into my possession it only presented to view vertical sections of the roots of the canine and molars split down longitudinally. Experimental chiselling disclosed the fine canine crown (*c*), besides the crown of an incisor (*i*) and crowns of two of the molars (*m* 5 & 6). The form and implantation of the roots had already led me to the conclusion that the animal belonged to the Theriodont order; and this inference was confirmed by the appearance of the canine and incisor crowns.

Between the canine and incisor is a diastema or toothless interval of ·37 inch. The latter slants backwards and outwards. Its crown is of a triangular form, and I am unable to detect any trace of serration; though it must be confessed that the anterior edge is not quite in a state to admit of a positive assertion. The tooth is not susceptible of further development from the matrix without risk of injury to the canine.

* Kindly given to me by Mr. Thos. Rickard, who has for several years studied the geology of the Kargalinsk strata and the conditions of the copper in their rocks.

Portion of Upper Jaw (right side) of Cliorhizodon orenburgensis, *Twelvetrees.* Nat. size.



i. Incisor. *c.* Canine. *m* 1–10. Molars.

Proceeding to the canine a fine recurved tooth is exhibited (*c*). It is thickest at the base of the crown and somewhat compressed laterally, though less so than the canines of any other Theriodonts that I have seen. Its posterior edge bears no sign of serration or crenulation. The interior is too mineralized to show reliably details of structure. Its exterior is faintly marked longitudinally. The root not being split quite in the median plane, the pulp-cavity is not displayed; but the form of the socket and of the implanted fang is instructively shown. The former is a cavity slightly narrowing towards its closed termination, and the root follows the same shape. The significance of such mode of implantation has been finely shown by Prof. Owen in his description of fragmentary indications of a huge kind of Theriodont reptile (*Titanosuchus ferox*, Ow.) from the Cape of Good Hope*. The present fossil is a remarkably good illustration of the views propounded in that memoir, and I am greatly indebted to its illustrious author for the guidance thereby afforded me. Not only the canine, but the molars too, which differ from the

* Quart. Journ. Geol. Soc. vol. xxxv. May 1879, pp. 189 *et seq.*

incisor in form as well as position, are inserted in separate sockets, which, together with the contained roots, taper to a more or less blunt but closed extremity.

m 1 is the root immediately behind the canine, from which it is not divided by any appreciable interspace. It is the longest molar root preserved.

m 2 & 3 are smaller and more slender roots exhibiting the elongated pulp-cavity, pointed extremity and closed sockets very decisively. Much the same may be said of *m* 4.

m 5 is the first we come to showing its crown, which was transversely broken in treating the fossil. It is small, subconical and directed backwards. Its anterior contour, which describes the greatest convex curve, is sharply serrated. Its root rises perpendicularly into a narrow socket, narrowing as it ascends.

m 6 is a larger molar, also exposing part of its crown, which seems to be of the same general shape and to have the same serration as that of *m* 5, but it is more swollen. Viewing the longitudinal outline of its root, there appears to me to be a very slight constriction or tendency to the formation of a cervix dividing the crown from the fang. The termination of this fang and its closed socket is less acuminate than in the preceding teeth. *m* 7 is a root not essentially different from *m* 6.

m 8 presents a complete longitudinal section of root and crown from the apex of the crown to the base of the fang. It evidences a backward slant of the crown and, as it seems to me, a barely perceptible constriction at the base of the latter. It exemplifies the closed socket quite as clearly as the other teeth; but the root gains a little in width upwards. At the base the corners are rounded off, and the base-line is punched up a little, so as to cause a slight undulation in the basal outline; and this corresponds to a similar wave in the basal outline of the pulp-cavity, which is large and conoidal, a facsimile of the root itself. The cavity is produced as a linear trace into the crown. *m* 9, partly preserved, resembles in form *m* 7, and *m* 10 is only a fragment.

	Incisor. in.	Canine. in.
Extraalveolar length (crown)	·38	1·3
From alveolar margin to end of fang (root)	...	1·1
Total......	...	2·4

Molars.

	1. in.	2. in.	3. in.	4. in.	5. in.	6. in.	7. in.	8. in.	9. in.	10. in.
Crown ...	...	...	...	...	...	·4	...	·29	...	...
Root......	·76	·41	·4	·48	·46	·44	·38	·35	·35	...
Total						·48		·64		

I have now passed in review the teeth seriatim. They point, in my opinion, to the location of the animal to which they belonged in the Theriodont order. The excessive obliquity of the root of the canine and the absence of the well-marked club-shaped outline characterizing the crowns of teeth of *Rhopalodon*, Fischer, are the reasons which have mainly influenced me in keeping it apart from that genus. In *Rhopalodon*, too, I have noticed a greater smoothness and more finely marked superficies of enamel. Venturing thus to distinguish it generically, and necessarily specifically, I submit the name of *Cliorhizodon orenburgensis*, in allusion to its contracting roots terminating in closed sockets, and to the government in Russia in which it was found.

Discussion.

Prof. Rupert Jones referred to the finding of reptilian remains in the dolomitic conglomerate of Bristol. It had been asserted that continental beds with similar reptiles were Permian, while it was now known that the former were Triassic; and he thought it should not be too hastily assumed that these Russian beds were Permian.

Prof. Boyd Dawkins said that the great feature of the Secondary rocks was the evolution of the Reptilia. The discovery, then, of so highly organized a group as Theriodonts was rather a reason for regarding these rocks as Secondary.

Prof. Seeley said he really did not know what a Theriodont was, and did not believe that, as a division of the Reptilia, the Theriodontia had any existence. What the specimen on the table was he could not say; and he did not think it was perfect enough for description.

Mr. Hulke thought the specimen too obscure for forming an opinion at once. He concurred with Prof. Seeley's remarks as to the dubious value of the Theriodontia as a natural family of reptiles. When the subject was some time since brought before the Society by Prof. Owen, he had stated that even teeth of the *Iguanodon* present characteristics supposed to be Theriodont.

The President said the teeth of these so-called Theriodonts were very different from those of the *Thecodontosaurus* and *Palæosaurus* of the Bristol conglomerate; but it was doubtful what was the true age of these so-called Permians.

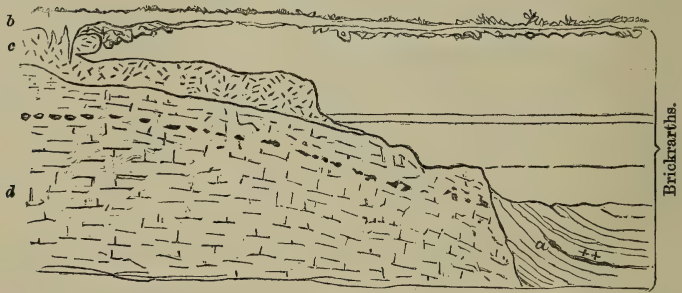
39. *On the* Discovery *of the* Place *where* Palæolithic Implements *were made at* Crayford. By F. C. J. Spurrell, F.G.S. (Read June 23, 1880.)

[Plate XXII.]

In the large chalk-pit at Crayford, Kent, and in the adjoining brick-pits I have noticed for some time flint flakes which I was unable to convince myself belonged to the brick-earths in which they were found, believing, from their shape, colour, and mineral condition, that they had come from another stratum of the river-deposits.

I, however, watched regularly, with great care, and during the late winter found a few flakes which, from their appearance, I felt belonged to the gently deposited brick-earths in which they lay; but they were solitary and rare, and it was not until the beginning of March last that, on the removal of a part of the face of the cliff, I came upon a dense layer of chips, specimens of which are exhibited.

Fig. 1.—*Section of Cliff at Crayford.*
(Scale $\frac{1}{35}$ inch to 1 foot.)



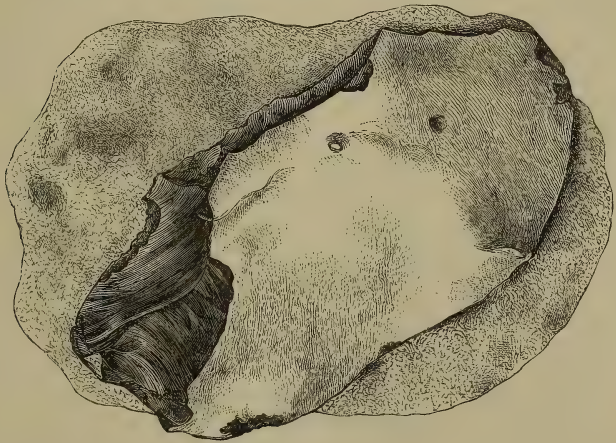
a. Layer of chips. *b*. Vegetable soil. *c*. Chalk rubble. *d*. Chalk. ++ Bones of *Rhinoceros*.

The sands and clays constituting the brick-earths of Crayford, lie under a low cliff of chalk and Thanet Sand, with a cap of gravel known as Dartford-Heath gravel. This ancient cliff (fig. 1) has in parts been worn lower than others; at one of these spots, where the wearing has invaded the chalk itself, the brick-earths are exposed lying against the chalk, which is much weathered and has the face covered with chalk-rubble; at the base of this section is a step in the chalk cliff, and a sort of foreshore seems to have been formed, consisting here of hard sand, and there of small heaps of flint stones brought down from the cliff above by aerial action. It is on one of these small slopes of sand that the layer of flakes was found. The uppermost edge of the area covered by them is about thirty-six feet from the present surface, the lowest nearly six feet lower. This area was thickly covered with chips for the space of about ten feet north and south, and, as far as I know at present, fifteen feet east and west, or parallel to the cliff; but I expect that it will be found to extend further.

The fragments of flint lay touching each other, in parts to a thickness of several inches, and had fallen so lightly that in several places there were minute cavities underneath the mass of larger and flatter flakes.

A few small pieces of bone were found immediately beneath the layer; but above could be seen fine specimens, and smaller ones in abundance, mostly incrusted with sand, cemented by iron oxide to the bones, and this occasionally included one or more flakes in the mass (fig. 2). Chips are found connected together by the same means.

Fig. 2.—*A Flint Flake which has been used at the side and butt end, adherent, by its upper surface, to a portion of the sandy matrix in which it was found imbedded.* Natural size.



The flakes, when first taken from the sand, are in most cases quite new and clean, always so on the lower side, very slightly discoloured with dust or iron on the upper. Many are studded with small concretions of white carbonate of lime.

Though the workman had abundance of material to work on, he seems to have found the flints very obstinate, as may be seen from the difficulty he had in procuring good heart pieces of flint and the patient way he chipped away the outside.

That he worked on the spot is evident. As I noticed before, the flakes lie lightly on each other; they are perfectly free from the slightest abrasion such as must have occurred had the edges rubbed over each other by the action of water; they did not fall from the cliff into the water, for occasionally long flakes broken in two have been seen, which could not have occurred had water intervened;

and notably one large flake was found by me, the broken ends facing each other as at the moment it fell and broke! A few small concretions remain on the opposed faces to show that the fracture was previous to the discovery and not due to an accident since.

Single flakes may be found above and below this layer, and it would therefore appear that the manufacture at this place was of long continuance.

Notwithstanding that many flakes were carried to "spoil" whilst I was absent, and the fall of some earth with the fear that more may follow prevents my getting the whole of these remains, I have been able to piece many of these flakes, and to demonstrate that the object sought was the manufacture of haches, which has been confirmed by my digging out, on the 23rd of April last, the broad end of a flint hache, in the presence of Prof. Boyd Dawkins, whom I had asked to visit the place; and later I recovered the rest of the implement.

Some of the smaller chips leave no doubt that, besides these coarser operations of blocking out, very fine work indeed was attempted.

All the parent stones have been derived from those found at hand and washed out of the cliff or fallen from it; not one had been rolled or dug out of the chalk by the workman, and all were slightly stained by iron before being used.

If I did not find the hammer, I found some such tool; but such pebbles as were required for the purpose could easily be obtained of various qualities from the Dartford Gravel above. Fints used for striking were found, however.

The bones with which these traces of man are associated are those of the brick-earth of Crayford in general, so completely described by Prof. Boyd Dawkins; but one specimen, which was found a few inches over the flints, is worthy of notice, being part of the distal end of the lower jaw of *Rhinoceros tichorhinus*, with four milk-teeth and the thin alveolar edges of the recently shed outer incisors uncrushed. The rest of that row of teeth were afterwards found about 18 inches off the first, the ends of the jaw having been rounded. From the body of the jaw had been extracted one uncut tooth of the coming series, which lay about a foot from the last; numerous splinters of the large bones lay around, and suggested their having been broken for food.

In the second section which I have prepared (fig. 3) is shown the relation of this deposit to other deposits of the same river in the immediate neighbourhood.

The oldest known to me is the widely spread tract of Dartford Gravel (*a*), extending many miles on either side of the present river Thames and bearing a definite relation on its northern as well as its southern confines to the course of that river. It is to be found resting with remarkable regularity on a level of about 98 feet above the ordnance datum line, whatever stratum it may rest on, though in pockets or pipes it occasionally descends lower. Its greatest thickness is about 35 feet. It is irregularly stratified; but as it has been repeatedly noticed in the Geological Society's Journal, I shall not further describe it.

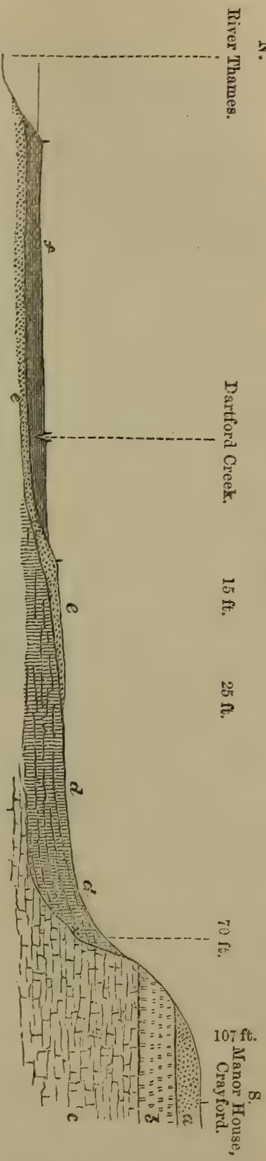
This gravel contains palæolithic implements. Some years ago I found a hache * *in situ* in it, on Dartford Heath, which is now in the British Museum; and this has been followed by Mr. C. C. S. Fooks (of The Bowman's Lodge, Dartford Heath) obtaining, last year, another from the same gravel, not quite so deep, however, and about 25 feet further south. I have found a few flakes, all bearing a general resemblance to each other in mineral character; and it is from this gravel that I believe some of the flakes that have been found in the brick-earths below have been derived.

It appears that the river afterwards left this level and descended not less than 180 feet (perhaps more than 200), cutting a deep channel, of which the cliff in my first section (fig. 1) is a result. When at its lowest, the river must have been comparatively a small one. The river then began to rise slowly until the water attained, if it did not exceed, its old supremacy.

It was during this rise that the brick-earths were deposited, some of which, containing elephant remains, have been found resting on chalk in the bed of the Thames in Erith Rands, about forty feet below the datum line.

Then the water retreated again, washing away much of

Fig. 3.—*Section from the Thames to the Manor House, Crayford.* (Horizontal scale 2 inches to 1 mile. Vertical scale $\frac{1}{150}$ in. to 1 foot.)



a. Dartford Gravel. *b.* Thanet Sand. *c.* Chalk. *d.* Brick-earth. *e.* Gravel. *f.* Alluvium. * Flint flakes.

* Figured in Mr. J. Evans's 'Ancient Stone Implements,' p. 532.

the upper layers of brick-earth, and giving much of the present form and slope to the lower part of the valley. At its close came down rushes of gravel, chiefly from the highest bed, crushing into the softer layer beneath, and making festoons and loops when seen in section; this is known by the name of "trail," and accumulated lower down in large banks, on which rests the alluvium of the prehistoric time.

EXPLANATION OF PLATE XXII.

Flint flakes found at Crayford, replaced in their relative positions around the hache, which lies within, forming a restoration of the block of flint as picked up on the neighbouring foreshore before being worked. Many of the constituent flakes have been used. (The flake marked "J. L." was found by Sir John Lubbock after the other fragments had been pieced together.)

Discussion.

Prof. Prestwich observed that this case was analogous to those of the Somme valley, where we had an upper- and a lower-level gravel with flint implements. He remarked on the great interest and novelty of the work of Mr. Spurrell.

Mr. Evans thought the discovery threw much light upon the relations of the beds and the manufacture of the flints. He called attention to the difference between the flakes from the brick-earths and the implements from the upper gravel. Many of the flint flakes were carefully wrought, and seemed to have been intended for flint knives. The Crayford deposit resembles that of Menchecourt, in which similar flakes and bones of *R. tichorhinus* had been found.

Prof. Bonney called attention to the fact that the incrustations and colour-stains passed over the cracks in the cases where the fragments had been fitted together to make a block. This perplexed him, and he could not help doubting whether the latter were not fractures caused by natural action, and not by the hand of palæolithic man.

Prof. Hughes saw difficulties in the way of accepting the evidence without further explanations. The flakes were left together, while the gravel and sand told of transporting currents. Moreover the flakes were not in the same condition as the other remains said to have been procured from the same formation; while the flints from which the flakes were struck did seem to have belonged, when whole, to that formation*.

Mr. Charlesworth mentioned a deposit at Hackney where implements were being found with *Cyrena fluminalis*.

Mr. Spurrell replied that some stains had commenced before the specimen was worked, while others were formed afterwards.

* [*Note.*—I am permitted to state in a note that since offering the above criticism on the evidence laid before the Society, I have examined the locality with Mr. Spurrell and have seen that the difficulties which occurred to me can be explained away by reference to the peculiar conditions of deposit at the foot of a chalk cliff, and that, having dug out many specimens with my own hands, I am convinced that the flakes are the work of man and that they do occur under at least 37 feet of the Crayford sand and gravel with the remains of *Rhinoceros* &c.—T. M'K. H.]

A.S. Foord del. et lith

RESTORED FLINT BLOCK.

Mintern Bros imp.

40. *On some new* Cretaceous Comatulæ. By P. Herbert Carpenter, M.A., Assistant Master at Eton College. (Read June 23, 1880.)

(Communicated by Prof. P. M. Duncan, M.B. Lond., F.R.S., V.P.G.S.)

[Plate XXIII.]

In the following pages I have described some new Cretaceous *Comatulæ* which have been placed at my disposal for this purpose since the publication of my paper on British Secondary *Comatulæ* in the February Number of this Journal (vol. xxxvi. pp. 36–55, pl. v.).

Two of the new species belong to the cabinet of the Rev. P. B. Brodie, M.A., F.G.S., who courteously offered them to me for description. The other three are in the Geological Collection of the British Museum, and (as before) I am indebted to the kindness of Dr. Henry Woodward, F.R.S., and of Mr. R. Etheridge, Junr., for the opportunity of examining them. To all of these gentlemen my best thanks are due.

1. Antedon perforata, n. sp. (Pl. XXIII. fig. 2.)

The centrodorsal is a thick pentagonal disk with steep sides and a hollowed dorsal surface (fig. 2, *b*). At the bottom of the hollow is an irregular central opening, and on its sloping sides are five others, radially disposed and separated by faint grooves. There are about fifty deep cirrhus-sockets, arranged rather irregularly; those which are best preserved show traces of striated margins and have small articular ridges crossing them at or slightly above the middle, which are pierced by the transversely oval openings of the cirrhus-canals (fig. 2, *c*). The ventral surface (fig. 2, *a*) is marked by various pits and hollows, but is tolerably flat on the whole, except that one of the radial areas falls away very much toward the periphery. The basal grooves are indistinct, with nearly parallel sides, which show faint traces of plication here and there; and the central cavity is irregularly five-rayed, with uneven margins and slight indications of radial ribs on its walls like those of *A. paradoxa*, the strong interradial ribs of which are absent in this specimen.

Diameter 11½ mm.; height 5 mm.

Locality. The (Upper) Chalk, Margate. Wetherell Collection, British Museum.

Remarks. The somewhat worn specimen described above resembles *A. paradoxa* in general appearance, but lacks the keyhole-shaped opening in the cirrhus-sockets characteristic of this species and of *A. rugosa* (fig. 4). One socket, it is true, has a central somewhat keyhole-shaped pit; but I believe this to be artificial. The rim around the opening of the axial canal has been worn away, and the opening thereby united with the deepest part of the dorsal ligament-pit which lies just beneath it; while the two disconnected ends of the articular ridge stand up on either side of the composite pit thus produced, so that the socket has somewhat the appearance of those of *A. paradoxa* or *A. rugosa*. On the other hand I have seen no cirrhus-socket in either of these species which shows any trace of an articular ridge surrounding a central opening. A considerable proportion of each socket (fig. 4) is occupied by the large keyhole-shaped pit. The opening of the axial canal was probably at the bottom of this pit, while there are small lateral elevations causing the constrictions of its sides that may be the disconnected ends of a transverse articular ridge. But I have been unable to satisfy myself that they are so, while it is unlikely that such an appearance would be always artificial. In any case, the appearance of the sockets, as we find them now, forms a good distinction between *A. paradoxa* and *A. rugosa*, on the one hand, and *A. perforata* with the remaining Cretaceous *Antedons* on the other. The latter species also differs from the two former ones in having six large and distinct openings at the dorsal pole, and not a simple five-rayed impression. The presence of the radial ribs on the walls of the axial cavity gives it an intermediate position between them; for while there are no ribs at all in *A. rugosa*, there are both interradial and radial ones in *A. paradoxa*. The radial ribs, the plaiting of the basal grooves, the depth of the cirrhus-sockets, and the form of their articular surfaces distinguish *A. perforata* from *A. Lundgreni*, to which we will now pass on.

2. Antedon Lundgreni, n. sp. (Pl. XXIII. fig. 3.)

The centrodorsal is irregularly hemispherical, with a rounded pentagonal outline, and is nearly covered by ten vertical rows of cirrhus-sockets (fig. 3, *b*, *c*). Each row is separated from its neighbours by more or less distinct ridges, and contains two or three sockets which have striated margins and minute central perforations. The precise shape of the articular surfaces is difficult to make out; it is most like that to be described immediately in *A. striata* (fig. 5). Rather to one side of the apex is an irregular hole with constricted sides. The ventral surface (fig. 3, *a*) is flat with indistinct basal grooves, the sides of which show no traces of plication, which would probably have been preserved had it existed, as the striation of the cirrhus-sockets is visible.

One of the grooves is occupied by a small prismatic basal, the outer end of which reaches the margin of the centrodorsal so as to appear externally (fig. 3, *c*). From its narrow inner end diverge two small bony bars. One of these, the right in the figure (3, *a*), is followed by two others, but the rest of the margin of the axial opening is rather irregular. Were it complete with all the basals *in situ*, it would evidently be decagonal and closely resemble the corresponding part in Goldfuss's figure of *A. paradoxa**. Just outside the margin of the opening are five small, but double radial pits. Each of these is very shallow and more or less separated into two parts by a tangential division, just as represented in Goldfuss's figure. The central cavity is tolerably deep, without any ribs on its walls.

* Petrefacta Germaniæ, Taf. li. fig. 1, *b*.

Diameter 5 mm.; height nearly 2·5 mm.

Locality. The (Upper) Chalk, Margate. Wetherell Collection, British Museum.

Remarks. The form and regular arrangement of the cirrhus-sockets and the want of plication of the basal grooves distinguish this species from both *A. paradoxa* and *A. rugosa*. The specimen described is of special interest from the proof which it furnishes of the correctness of Lundgren's explanation * of the so-called 'ambulacra' of *A. paradoxa* as the grooves in which the basals are lodged. I have much pleasure therefore in naming the species after him.

3. Antedon striata, n. sp. (Pl. XXIII. fig. 5.)

The centrodorsal is a roughly circular thick disk with steep sides and a deepish hollow at the dorsal pole, on the sloping wall of which is a faint trace of a stellate impression (fig. 5, *c*). It bears numerous cirrhus-sockets in four or five irregularly alternating rows, probably about forty in all, if the portion concealed by the matrix be allowed for. They have a circular or oval shape, the largest reaching nearly 2 mm. in diameter. Each is a deepish hollow with a very distinctly striated rim, and at or just above the middle a small opening, which is usually somewhat elongated transversely and has slight elevations around its ends (fig. 5, *c*). These are seen in the best-preserved sockets to be the more prominent parts of a thick articular rim which surrounds the opening of the cirrhus-canal (fig. 5, *d*).

The ventral surface is very flat and rather obscured by the matrix, which occupies the stellate central cavity and conceals the inner ends of the basal grooves. These seem to have been pear-shaped, and their sides show no indications of plaiting, which, had it existed, would have been preserved like the striæ of the cirrhus-sockets.

Diameter nearly 9 mm.; height $4\frac{1}{2}$ mm.

Locality. The (Upper) Chalk, Dover. British-Museum Collection.

Remarks. This species has a considerable superficial resemblance to *A. rugosa*, but its centrodorsal is rather higher and bears more cirrhi, the sockets of which are quite different from those of that type. They are more like those of *A. Lundgreni*, but are arranged quite differently and are far more distinctly striated. In *A. phalangium* of the Mediterranean the margins of the cirrhus-sockets are quite plain; but the articular rim around the opening of the axial canal has very much the same shape that it has in *A. striata*.

4. Antedon laticirra, n. sp. (Pl. XXIII. fig. 6.)

The centrodorsal is roughly hemispherical with a pentagonal outline, and bears eight cirrhus-sockets in a single incomplete row

* "Om en *Comaster* och en *Aptychus* från Köpinge," Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, 1874, p. 65.

(fig. 6, *b*, *c*). The dorsal pole is smooth and slightly flattened. Most of the sockets, are large and pear-shaped with the small end downwards, the largest being nearly $2\frac{1}{2}$ by $1\frac{1}{2}$ mm. An articular ridge crosses the broadest part and widens out in the centre round the transverse opening of the axial canal. The margins of the sockets are coarsely striated.

The ventral surface has a shallow and irregular central cavity, with traces of small radial extensions (fig. 6, *a*). The basal grooves are well marked, with high parallel walls that stand up above the level of the intervening radial areas, which are more or less irregularly hollowed (fig. 6, *c*).

Diameter 4 mm.; height about $3\frac{1}{4}$ mm.

Locality. The Chalk of Wylye, in Wiltshire. Both this and the following species belong to the cabinet of the Rev. P. B. Brodie, M.A., F.G.S., who has kindly placed them in my hands for description.

Remarks. The few but large cirrhus-sockets of this species and its deeply cut basal grooves distinguish it very markedly from the other fossil *Comatulæ*. The sockets of *A. paradoxa* are sometimes as long, but they have entirely different articular surfaces (fig. 4).

5. Antedon incurva, n. sp. (Pl. XXIII. fig. 1.)

The centrodorsal is hemispherical, with a pentagonal outline, and is almost completely covered by about forty-five polygonal cirrhus-sockets, arranged in five or six more or less irregularly alternating rows. At the dorsal pole is a trace of a stellate impression (fig. 1, *b*). The margins of the sockets are striated, and the transversely oval opening of the central canal seems to have had a rim with raised ends as in *A. striata* (fig. 5, *d*).

The sides of the radial pentagon are rather curved inwards, so that it does not quite cover the centrodorsal (fig. 1, *a*), while its angles project slightly beyond the edge. The outer dorsal surfaces of the radials are just visible, especially at the angles, where they are turned upwards and separated by small rounded basals that project slightly outwards, so as to be visible when the calyx is viewed from either above or below (fig. 1, *a*, *b*).

The articular faces of the radials are high relatively to their width and much curved from above downwards, as well as from side to side (fig. 1, *c*, *d*). Only one of them is at all free from the matrix. It shows a considerable enlargement of the ventral rim of the axial canal, from which a median ridge runs upwards to meet a wide notch between the muscle-plates, while two others run upwards and outwards to separate the muscular fossæ from those for the interarticular ligaments. The form of the central funnel is stellate, but somewhat irregular; for at three of the angles there is no notch between the muscle-plates of two adjacent radials, while at two others these notches are visible, owing to the tips of the plates being somewhat everted.

Diameter $4\frac{1}{2}$ mm.

Locality. The Upper Greensand, Blackdown. Collection of the Rev. P. B. Brodie, M.A., F.G.S.

Remarks. This is a very singular type, as it presents a combination of several characters which are more or less distinctive of various other Cretaceous species and of some recent ones. In its general *facies* this fossil resembles the corresponding part of *A. celtica* and *A. Eschrichtii* of the North-Atlantic basin. The latter species is the more like it, having a hemispherical centrodorsal with a pentagonal outline and very similar articular faces, including the enlargement of the ventral rim of the axial canal. The two types differ, however, in points of detail, such as the lateral curvature of the articular faces of *A. incurva,* so that the radials do not completely cover the centrodorsal; and they show a small outer dorsal surface, the flanks of which are upturned above the outer ends of the basals. Both these characters are common to *A. semiglobosa* and *A. æquimarginata.* In the former species, however, the upper ends of the apposed lateral edges of the radials stand out more prominently than in *A. incurva*; while the articular faces of *A. æquimarginata* have a very straight slope and lack the ventral intermuscular notch which occurs in *A. incurva*, though the enlargement of the upper rim of the axial canal is common both to it and to the recent *A. Eschrichtii.*

The lateral curvature of the articular faces occurs in a new Pacific *Antedon* (otherwise very different), in *A. lenticularis*, *A. italica*, and in the so-called *Hertha mystica* * from the Cretaceous series of the island of Rügen. There is a further resemblance to this last species in the projection of the angles of the radial pentagon beyond the margin of the centrodorsal, so that they are visible when the calyx is viewed from below (fig. 1, *b*); but the ventral aspect of the calyx is very different from that of *Hertha*, in which the articular faces suddenly narrow very much near their ventral ends, while Hagenow could discover no external basals, such as we find in *A. incurva.*

The close grouping of the cirrhus-sockets on the centrodorsal of this species, and the faint stellate impression at its dorsal pole, give it a certain resemblance to *A. rotunda*; but its pentagonal shape is sufficient to distinguish it, apart from other slight differences.

In the following table (p. 554) I have endeavoured to show the occurrence of characters belonging to this species in other *Comatulæ.*

* Von Hagenow, "Monographie der Rügen'schen Kreide-Versteinerungen: II. Abtheilung, Radiarien und Annulaten," Neues Jahrb. f. Mineral. 1840, p. 664.

Table showing the distribution of certain characters of A. incurva *in other* Comatulæ.

	Characters of *Ant. incurva.*	*A. rotunda.*	*A. æquimarginata.*	*A. semiglobosa.*	*A. mystica.*	*A. lenticularis.*	*A. italica.*	*A. Eschrichtii.*	*Antedon,* n. sp.
Formation.	Upper Greensand.	Lower Greensand.	Gault.	Grünsand von Speldorf.	Upper Chalk.	Maestricht Chalk.	Eocene.	North Atlantic.	Pacific.
1.	Centrodorsal nearly hemispherical...	*	......	*	*	......	......	*	*
2.	Its outline pentagonal	......	*	*	......	......	*	*	*
3.	Cirrhus-sockets numerous	*	......	*	......	*	*	*	
4.	Their margins striated	*	......	*					
5.	Radials do not cover centrodorsal, and their outer dorsal edges are more or less curved inwards	Radials unknown.	*	*	*	*	*	......	*
6.	Angles of radial pentagon project beyond edge of centrodorsal		......	......	*				
7.	Outer dorsal surface small, with upturned flanks		*	*					
8.	A large articular surface above opening of axial canal...............	......	*	......	......	......	......	*	

I append a key to the various species of *Antedon* from the English Chalk which have been described in this and in my preceding paper.

Antedons *from the English Chalk.*

I. Cirrhus-sockets with a keyhole-shaped pit.	
A. Centrodorsal cavity has ribbed walls	1. *A. paradoxa.*
B. Walls of centrodorsal cavity plain	2. *A. rugosa.*
II. Cirrhus-sockets have an oval articular surface slightly elevated at the ends.	
C. Ten vertical rows of cirrhus-sockets	3. *A. Lundgreni.*
D. Sockets numerous in alternating horizontal rows..	4. *A. striata.*
III. Cirrhus-sockets have a transverse articular ridge.	
E. Sockets numerous in irregular rows. Six apertures at dorsal pole	5. *A. perforata.*
F. Few sockets in one incomplete row. Dorsal pole imperforate..	6. *A. laticirra.*

In conclusion, I wish to say a few words on a morphological subject which was alluded to in my previous paper (pp. 37, 38), and has recently gained in interest from the writings of Messrs. Wachsmuth and Springer.

In recent *Comatulæ*, as in *Pentacrinus*, the lowest portions of the cœlom of the arms are lodged in the median ventral furrows of their skeleton, which terminate in those of the rays. The latter are continued down the inner faces of the first radials, where they are more or less completely converted into canals that end blindly against the upper surface of the centrodorsal. They are sometimes received into five radial pits, which are very deep in certain fossil *Comatulæ*. This is the case in *Ant. Retzii*, in which they remain outside and separate from the median cavity of the centrodorsal that lodged the chambered organ, being shut off from it by vertical partitions. In *A. semiglobosa* the central cavity is united (perhaps by accident) with the five others round it and has a stellate appearance, while there is a similar stellate pit on the under surface of the centrodorsal. Stellate dorsal pits slightly smaller in size occur in other fossil *Comatulæ*; these are far larger than was necessary merely to transmit the vascular axis of the larval stem, continued downwards from the chambered organ. One is led to suspect, therefore, that they gave passage, not only to this central axis, but also to five radial extensions of the body-cavity around it, the radial pits of other *Comatulæ* being here represented by real perforations through the substance of the centrodorsal.

The condition of *Ant. perforata* tends to support this view. On its ventral surface (Pl. XXIII. fig. 2, *a*) the radial pits are more or less confluent with the central cavity, but dorsally (fig. 2, *b*) there are six separate openings, a central one and five others around it corresponding to the radial extensions of the axial cavity above.

This question is of interest in reference to the hypothesis recently put forward by Messrs. Wachsmuth and Springer *, "that the

* "Revision of the Palæocrinoidea.—Part i.," Proceed. Acad. Nat. Sci. Philad. 1879, p. 15 (separate copy).

column was in some cases, and perhaps more or less in the Palæocrinoids generally, subservient to respiration." According to these authors, some of the Palæocrinoids had hydrospires like those of the Blastoids; but there are a large number of forms in which no trace of them has as yet been discovered. They suggest therefore that the complex stem which many of the Palæocrinoids possess "was a means of communication between the water outside and the internal organs of the body for some purpose," probably respiratory. In some groups, such as the Platycrinidæ, the stem is destitute of any internal structure, but is simply pierced by a very small central canal, which lodged the vascular axis. This canal is of very small size in *Pentacrinus*; but it is sufficient to contain six vessels, a central one and five peripheral ones, which in the nodal joints send branches into the cirrhi. In the fossil *Pentacrini* the central canal of the stem is very small, just as in the recent species. It is also small in *Encrinus*, and its upper end is enclosed by the circlet of five under basals, each of which bears a slight pit on its ventral surface. These pits, which are radial in position, are the dorsal ends of the furrows that descend the sloping ventral faces of the radials. At the margin of the calyx they are continuous with the more or less distinct grooves along the ventral surface of the skeleton of the rays and arms, just as in *Comatula* and *Pentacrinus*. The radial pits of *Encrinus* are thus precisely homologous with those on the upper surface of the centrodorsal in *Comatula*. If, instead of being pits, they were perforations through the under basals, the lower surface of the calyx would show five large apertures surrounding a central one, instead of that central one only.

This condition, or a parallel one, is precisely what we do find in some fossil Crinoids. In *Nannocrinus* and *Myrtillocrinus* * the body is pentamerous, but the stem only tetramerous; and there are five apertures on the under surface of the calyx. Judged by the standard of *Pentacrinus* and *Rhizocrinus*, the central one is more than large enough to have lodged the vascular axis; while there are four peripheral ones which lodged, I believe, downward prolongations of the cœlom. In one species of *Epactocrinus* (*E. antiquus*) the base of the calyx has five separate apertures, while in another (*E. irregularis*) there is but one large cruciform opening taking up nearly the whole of the top stem-joint. This looks as if the central aperture had fused with the four peripheral ones. The same must have been the case in *Cupressocrinus*, in which the under surface of the calyx shows a four- or five-rayed perforation, while the stem-joints have four or five separate openings around a large central one. This is relatively far larger than that of a *Pentacrinus*-stem, and is sometimes four- or five-lobed, as if corresponding to the four or five peripheral vessels of the vascular axis. What, then, could have been lodged in the peripheral canals of the stem but tubular extensions of the body-cavity homologous with those which end on the centrodorsal piece of most *Comatulæ*? In *Ant. perforata*, and

* See Quenstedt's 'Petrefactenkunde Deutschlands,' Bd. iv. "Asteriden und Encriniden," tab. 108.

possibly also in other species, they would seem to have extended into the larval stem. Whether they remained open after the stem was discarded, or whether their openings were closed up in the interior of the centrodorsal, must of course remain uncertain.

It seems to me very probable that the large and subdivided internal cavities of the stems of *Barycrinus* and of the other genera mentioned by Wachsmuth and Springer may have contained water surrounding the central vascular axis, just as supposed above for *Cupressocrinus* and for certain *Comatulæ*. But these authors further suppose that "there was ample communication with the surrounding water" through the numerous branches at the base of the stem, all of which are perforated. It is of course possible that the canals in the rootlets of these large stems were not solely occupied by the vessels, as is the case in the radicular cirrhi of *Rhizocrinus*; but it seems to me far less likely that these canals opened at the ends of the rootlets, concealed as these were below the surface of the ooze. The water entering (?) the stem by these passages would hardly have been very useful for respiratory purposes.

On the other hand it is not unlikely that the "large pores near the base of the column, leading from without into the main cavity directly through the walls," may have served to admit water into the stem and thence into the cœlom. The observations of Wachsmuth and Springer that the complex perforated stems occur almost exclusively in those forms which are destitute of hydrospires, or of pores in the calyx, seem to point to this conclusion; but there is another possible mode of communication between the cœlom and the exterior, to which they do not refer.

All recent Crinoids known to us have very minute ciliated pores scattered over the perisome of the disk and the bases of the arms and leading into the cœlom. Müller * has pointed out the correspondence of this system of pores with the hydrospires of the Cystids (*e.g. Caryocrinus*), and further research may reveal their presence in those Palæocrinoids in which no hydrospires have yet been discovered. So far as I know, they have not been looked for in these forms in the same positions that they occupy in recent Crinoids, these parts being rarely well preserved. In the recent species the pores are scattered about on the surface of the disk and arm-bases in the neighbourhood of the ambulacral grooves. When the perisome is plated as in *Pentacrinus* and many *Comatulæ* the water-pores occur on some of the anambulacral plates which are close to the side plates of the grooves. In the Palæocrinoids, however, the surface of the body bearing the grooves was not the external surface, as it was covered in by the vault of rigid heavy plates. But there must have been a free admission of water beneath this vault by the so-called ambulacral openings where the food-grooves of the arms extended over the disk towards the subtegminal mouth. May not the areas of the body between these grooves have been provided with ciliated pores leading into the cœlom, like those of recent Crinoids?

* "Ueber den Bau der Echinodermen," Abhandl. d. königl. Akad. d. Wissensch. zu Berlin, 1854, p. 64 (separate copy).

In *Pentacrinus* and in the *Comatulæ* the water-pores are numerous; but in *Rhizocrinus* there is only one in each interradius, and in correspondence with them there are five open tubes depending from the water-vascular ring into the cœlom. These water-tubes, which are more numerous in *Pentacrinus* and in the *Comatulæ*, serve to admit water into the ambulacral system. Wachsmuth's observations render it probable that there were five in *Actinocrinus* as in *Rhizocrinus**. May one not infer from this that there were five (or more) water-pores on the disk, through which water was admitted into the cœlom on its way to enter the ambulacral ring by the water-tubes?

EXPLANATION OF PLATE XXIII.

Fig. 1. *Antedon incurva*, n. sp., from the Upper Greensand, Blackdown. Centrodorsal and radial pentagon. *a*, from above; *b*, from beneath; *c*, from the side, interradial view; *d*, from the side, radial view. ×6.

2. *Antedon perforata*, n. sp., from the Upper Chalk, Margate. Centrodorsal. *a*, ventral surface; *b*, dorsal surface. ×2. *c*, cirrhus-socket, enlarged.

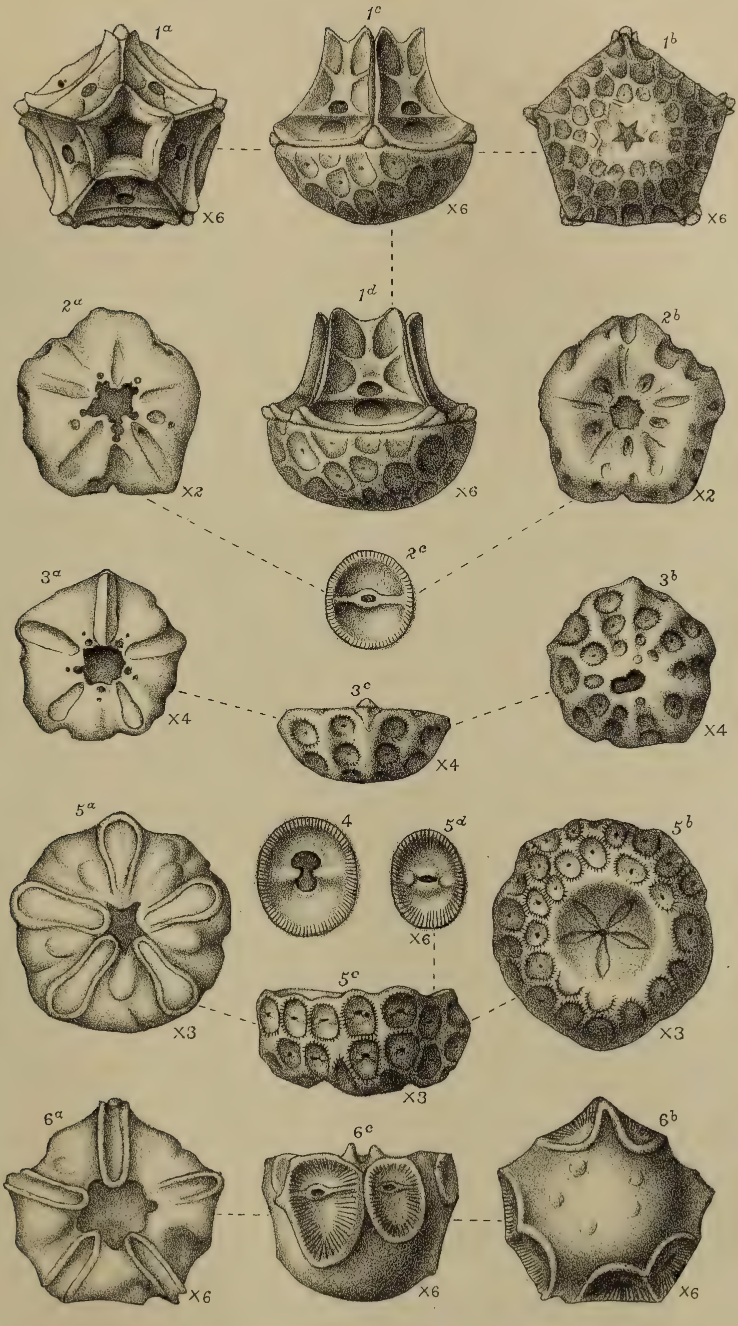
3. *Antedon Lundgreni*, n. sp., from the Upper Chalk, Margate. Centrodorsal and single basal. *a*, ventral surface; *b*, dorsal surface; *c*, from the side. ×4.

4. Cirrhus-sockets of *Antedon rugosa*.

5. *Antedon striata*, n. sp., from the Upper Chalk, Dover. Centrodorsal. *a*, ventral surface; *b*, dorsal surface; *c*, from the side. ×3. *d*, cirrhus-socket, enlarged.

6. *Antedon laticirra*, n. sp., from the Chalk of Wiltshire. Centrodorsal. *a*, ventral surface; *b*, dorsal surface; *c*, from the side, interradial view. ×6.

* "The Oral and Apical Systems of the Echinoderms," Quart. Journ. Microsc. Science, vol. xix. pp. 185, 186.



Berjeau lith.

Hanhart imp.

CRETACEOUS COMATULÆ.

41. *On the* ZONES *of* MARINE FOSSILS *in the* CALCIFEROUS SANDSTONE SERIES *of* FIFE. By JAS. W. KIRKBY, Esq. (Read June 23, 1880.)

(Communicated by Prof. T. Rupert Jones, F.R.S., F.G.S.)

THE presence of marine beds in the Calciferous Sandstones of the east of Scotland has been noticed by various authors. The officers of the Geological Survey, for example, draw attention to their occurrence in the neighbourhood of Edinburgh and in East Lothian, in their memoirs of those districts *. The Rev. Thomas Brown also gives an account of several beds containing marine fossils in his paper on the Carboniferous strata of Fife †; and, more recently, Mr. R. Etheridge, jun., has published a paper, in the Journal of this Society, on the Invertebrate fauna of the rocks of this series in the vicinity of Edinburgh, which includes all the marine species known to him from that district ‡.

As supplementary to these and other notices, I propose in this paper to describe the marine beds that I have met with in an examination of the Calciferous Sandstones of the east of Fife. These beds I shall notice in their descending order of position, together with such details of the intermediate measures and fossils as may assist in the attainment of a general idea of the palæontology of the formation.

In the east of Fife these rocks form the coast-line from near St. Monan's, on by Fife Ness, to St. Andrew's; but the most complete section is that exposed at their first outcrop, at a point east of the first-named place to Anstruther, a distance of two miles or more. The strata of this section dip to the west, usually at a high angle, and the thickness exposed exceeds 3900 feet. Unfortunately at this depth the dip is reversed, so that the junction of the basement beds of the series with the underlying Old Red Sandstone is not seen. To this extent the section is incomplete, and there is no other on the Fife coast to show what is here wanting; so that there may possibly be marine strata of still earlier date in the Carboniferous series of the east of Scotland than any to be noticed in this paper.

Notwithstanding the great thickness of strata shown in this section, the whole of it is probably included in the "Cementstone Group" of the Geological Survey. At least there is nothing seen like the lowest or "Cornstone Group" as described by Prof. Geikie and his colleagues in the memoirs on the districts south of the Forth. The lowest strata exposed at Anstruther are pretty much the same in character as the measures above, though perhaps rather

* Geology of the Neighbourhood of Edinburgh, 1861, pp. 18, 30, 146. Geology of East Lothian, 1866, pp. 28, 73.

† Trans. Royal Society of Edinburgh, 1860, vol. xxii. pp. 398-400. See also Quart. Journ. Geol. Soc. 1859, vol. xv. p. 59.

‡ Quart. Journ. Geol. Soc. 1878, vol. xxxiv. p. 1.

more argillaceous; and the thin impure limestones or "cement-stones" occur within fifty feet or so of the outcrop of the lowest beds.

PITTENWEEM AND ANSTRUTHER SECTION (See fig. 2, p. 571).

The highest beds of the Calciferous Sandstones are seen to the east of the Coal Farm, midway between St. Monan's and Pittenweem, rising from beneath a thick, light-coloured, subcrystalline limestone (apparently equivalent to the Gilmerton Limestone of Mid Lothian and the Hurlet Limestone of the west of Scotland) which is given as the base of the overlying series in the Fife maps of the Geological Survey. In this bed are great quantities of *Lithodendron junceum* and other corals, *Orthis resupinata*, *Rhynchonella pleurodon*, *Athyris Royssii*, and other species characteristic of the Carboniferous Limestone. In the shale immediately below are numerous examples of *Myacites sulcatus*, *Aviculopecten arenosus*, *Myalina Verneuili*, *Schizodus axinfiormis*, and *Lingula squamiformis*, which may be taken as belonging to the same zone of fossils.

Then follow nearly 100 feet of sandstone and sandy fireclay or shale, containing traces of *Lepidodendron* and *Stigmaria*. These form the highest strata of the Calciferous Sandstones, if we take the thick limestone already mentioned as the base of the overlying series, which is probably as good a conventional line of division as could be chosen. We then reach about 4 feet of dark shale, with two bands of limestone containing marine fossils. This is the highest marine zone of the series, and from it have been obtained the following species, all of which are common to the Carboniferous Limestone:—

Fossils of Zone No. 1, 97 *feet below the base of the Carboniferous Limestone.*

Nautilus quadratus, *Fleming.*
Loxonema rugifera, *Phillips.*
Aviculopecten interstitialis, *Phillips.*
—— depilis ?, *M'Coy.*
Avicula, sp.
Pteronites persulcatus, *M'Coy.*
Arca Lacordairiana, *De Koninck.*
Cypricardia, sp.
Edmondia rudis, *M'Coy.*
Nucula, sp.
Sanguinolites tricostatus, *Portlock.*
Rhynchonella pleurodon, *Phill.*
Productus longispinus, *Sow.*
—— semireticulatus, var concinnus, *Sow.*
—— punctatus, *Martin.*
—— aculeatus, *Mart.*
Terebratula hastata, *Sowerby.*
Chonetes polita, *M'Coy.*
Spirifera trigonalis, *Martin.*
Athyris ambigua, *Sow.*
Fenestella plebeia, *M'Coy.*
Lithodendron junceum, *Flem.*

200 feet of measures intervene before the next marine zone is reached. These measures consist chiefly of sandstone in thick beds, shale, and four thin coals and their fireclays. The only fossils seen in them are the remains of *Lepidodendron* and *Lepidophyllum*. Then follows a two-feet bed of hard, grey, crinoidal limestone. From it and the shale immediately associated with it there have been obtained the following fossils :—

Fossils of Zone 2, at 290 feet.

Bellerophon decussatus, *Flem.*
Macrocheilus imbricatus, *Sow.*
Pleurotomaria, sp.
Orthis resupinata, *Mart.*
Productus semireticulatus, var. concinnus, *Sow.*
Chonetes polita, *M'Coy.*
Leperditia Okeni, *Münster.*
Crinoidal remains.
Small Ganoid scales.

About 30 feet of shale and sandstone intervene, containing *Sphenopteris affinis*, Stigmarian rootlets, and other obscure plant-remains. Below which come 20 feet or more of grey shale with ribs of calcareous ironstone, and near the base a two-feet bed of limestone containing a numerous suite of marine fossils.

Fossils of Zone 3, at 320 feet.

Bellerophon decussatus, *Flem.*
Dentalium priscum, *De Kon.*
Euomphalus carbonarius, *Sow.*
—— catillus, *Mart.*
Macrocheilus acutus, *Sow.*
Murchisonia striatula, *De Kon.*
—— quadricarinata, *M'Coy.*
Naticopsis plicistria, *Phill.*
Pleurotomaria Yvanii, *Lév.*
Avicula recta ?, *M'Coy.*
Aviculopecten ornatus ?, *Eth.*
—— sp.
Cypricardia oblonga, *M'Coy.*
Edmondia rudis, *M'Coy.*
Leda attenuata, *Flem.*
Myalina sublamellosa, *Eth.*
Pteronites persulcatus, *M'Coy.*
Sanguinolites abdensis, *Eth.*
—— plicatus, *Portlock.*
—— sp.
Schizodus axiniformis, *Phill.*
Lingula mytiloides, *Sow.*
Productus semireticulatus, var. concinnus, *Sow.*
—— Youngianus ?, *Dav.*
Fenestella, sp.
Crinoids.
Bairdia plebeia, *Reuss.*
Beyrichia radiata, *J. & K.*
Kirkbya permiana, *Jones.*
Leperditia Okeni, *Münst.*
—— ——, var.
Serpulites carbonarius, *M'Coy.*

The most characteristic species is *Sanguinolites abdensis*, which is found in great numbers. *Productus semireticulatus* is abundant in and near the limestone; but Lamellibranchs are the prevailing fossils. There are no corals.

Nearly 150 feet of alternating strata of shale with bands and nodules of ironstone, sandstone, and fireclay intervene, among which are three or four coaly beds with underclays containing Stigmarian rootlets. The only other fossils noticed are *Lepidodendron* sp., *Calamites* sp., and *Sphenopteris affinis*, as well as some obscure seed-vessels. There then occur, in the middle of a thick bed of shale containing the remains of plants near the top and below, the following marine species:—

Fossils of Zone 4, at 500 feet.*

Aviculopecten, sp.
Lingula mytiloides, *Sow.*
Productus cora, *D'Orbigny.*

From the last-named bed across the outcrop of nearly 1800 feet of strata (exposed in front and to the west of Pittenweem), I

* Zones 1, 2, 3, & 4 are seen between tide-marks and in the low cliffs some distance west of Pittenweem.

have not seen any deposits that can be described as marine from their organic remains. These strata consist of repeated alternations of white, yellow, and purplish sandstones, and grey, purplish, and black shales, fireclays, and occasionally marls, with ironstone in bands and nodules. Several of the sandstones form beds from 30 to 100 feet thick; and in one or two cases they become coarse and gritty and full of quartz pebbles; they are also characterized by false-bedding, and many of them are beautifully rippled.

Intercalated in this mass of strata are eighteen or more thin coals, from 3 inches to a foot in thickness, each with its underclay full of Stigmarian rootlets; and at various horizons there are beds of limestone, some of which are highly siliceous, and all more or less impure.

The remains of plants are scattered pretty generally through the argillaceous beds of these strata, though often in very imperfect condition. Of the determinable forms, *Lepidodendron* and *Sphenopteris affinis* are by far the most common; a species of *Calamites* occurs rarely; and some of the shales overlying the thin coals are full of the flattened and coarsely furrowed trunks and short upright stools of large trees. The scales and teeth of small Ganoid fishes are found in various beds; the remains of *Rhizodus Hibberti* and other large fishes are of rarer occurrence. A few species of Ostracoda are abundant at certain horizons, *Leperditia Okeni*, var. *scotoburdigalensis*, being the most characteristic. The following are the most notable fossiliferous zones in this section of strata:—

At 828 feet there is a two-feet bed of shale and blackband ironstone containing *Anthracomya scotica*, *Leperditia Okeni*, var. *scotoburdigalensis*, *Carbonia fabulina*, *C. Rankiniana*, and *Lepidodendron* sp.

At 923 feet, in a grey shale with ironstone bands, immediately overlying a curious pseudo-brecciated limestone, there are found the following species:—*Rhizodus Hibberti* *, *Ctenacanthus* sp., *Leperditia Okeni*, var. *scotoburdigalensis* *, *Lepidophyllum*, *Sphenopteris affinis*, and other plant-remains. The species with asterisks are exceedingly abundant in this bed; the *Leperditia* is also equally prevalent in a stratum of dark shale about ten feet below.

At rather over 2100 feet, behind the east pier of Pittenweem Harbour, there is a bed of dark calcareous shale full of the remains of a curious, linear, polyzoiform plant, which is probably a fucoid.

A little below, at 2120 feet, the scales of *Rhizodus Hibberti* again occur in black shale, along with the remains of *Rhadinichthys brevis* ?, Traquair, and *Ctenodus* sp.

Then, at the depth of 2280 feet, one of the most important marine zones of the series comes into section. This deposit, which the Rev. Thomas Brown first described, consists of about 20 feet of dark shale, with layers of ironstone nodules and two or more thin bands of limestone. Directly beneath it is a twelve-inch seam of coal, resting on a thin shale or fireclay full of Stigmarian rootlets; it is well exposed in the cliffs and between tide-marks, a little to the east of Pittenweem Harbour, where it has yielded me the following fossils :—

Fossils of Zone 5, *at* 2280 *feet* (the Encrinite-bed of Mr. Brown's paper).

Nautilus quadratus, *Flem.*
Orthoceras attenuatum, *Flem.*
Bellerophon decussatus, *Flem.*
—— Urii, *Flem.*
Dentalium priscum, *Goldfuss.*
Loxonema scalaroidea, *Phill.*, and variety.
Macrocheilus acutus, *Sow.*
—— fusiformis, *Sow.*
Murchisonia striatula, *De Kon.*
—— sp.
Naticopsis, sp.
Pleurotomaria Yvanii, *Lév.*
Aviculopecten arenosus, *Phill.*
—— granosus, *Phill.*
—— fimbriatus, *Phill.*
Cypricardia, sp.
Leda attenuata, *Flem.*
Leptodomus costellatus, *M'Coy.*
Nucula gibbosa, *Flem.*
Schizodus unioniformis, *Phill.*
—— carbonarius ?, *Portl.*
Venus ?, sp.
Athyris ambigua, *Sow.*
Discina nitida, *Phill.*
Productus semireticulatus, var. Martini, *Sow.*
Spiriferina cristata, *Schlotheim.*
Streptorhynchus crenistria, *Phill.*
Bairdia plebeia, *Reuss.*
—— Hisingeri, *Münst.*
—— brevis, *J. & K.*
—— subelongata, *J. & K.*
Beyrichia subarcuata, *Jones.*
—— radiata, *J. & K.*
Cythere, sp.
Archæocidaris Urii, *Flem.*
Actinocrinus, Poteriocrinus, Platycrinus (fragmentary remains of the calyx and stem of species belonging to these three genera).
Spirorbis helicteres, *Salter.*
Stenopora tumida, *Phill.*
Plants—large and small fragments of stems, belonging to *Lepidodendron* and *Dadoxylon.*

The Crinoidal remains are very abundant about and in the limestones. The most characteristic fossils among the Mollusca are the species of *Leda*, *Nucula*, *Discina*, *Productus*, and *Spiriferina*, some of which more especially mark certain horizons of the bed.

Most of the species are found in the shale close to the coal, as well as higher up, though some of them are there rather dwarfed, the Univalves and Crinoids more particularly. One of the most common fossils in this position is the *Productus*, which occurs with its long and slender spines attached to the shell, within an inch or so of the coal.

A little to the east of the Rock and Spindle, near St. Andrews, there is a shale with a band of crinoidal limestone, which I take to be the same bed as this. In it are found the following species :—*Orthoceras attenuatum*, *Bellerophon Urii*, *B. decussatus*, *Dentalium scoticum*, *Euomphalus acutus*, *Murchisonia striatula*, *Aviculopecten granosus*, *A.* sp., *Edmondia rudis*, *Leda attenuata*, *Schizodus axiniformis*, *Lingula mytiloides*, *Productus semireticulatus*, var. *Martini*, *Spiriferina cristata*, *Rhynchonella pleurodon*, *Fenestella tuberculocarinata*, *Stenopora tumida*, and a few small Ganoid scales. The crinoidal remains are smaller than at Pittenweem, but apparently belong to the same genera.

About 40 feet below the Encrinite-bed is a four-inch band of very hard limestone, full of the shells of *Myalina modioliformis*. This is the highest horizon at which I have observed this gregarious shell, so characteristic of the lower portion of the Calciferous Sandstones.

Fossils of Zone 6, *at* 2320 *feet.*

Naticopsis? sp.	Carbonaria subula?, *J. & K.*
Myalina modioliformis, *Brown.*	Ganoid scales.
Carbonia Rankiniana, *J. & K.*	Plant-remains.

Twenty feet or so further down is another impure limestone, about six inches thick, in which a little univalve, *Littorina scotoburdigalensis*, is the prevailing fossil *.

Fossils of Zone 7, *at* 2350 *feet.*

Littorina scotoburdigalensis, *Eth.*	Leperditia Okeni, *Münst.*
—— bilineata, sp. nov.	—— ——, var.
Kirkbya spiralis, *J. & K.*	

The strata associated with the marine zones Nos. 5, 6, and 7 contain the remains of plants, Entomostraca, and other fossils; but this part of the section is so illustrative of the way in which beds of different structure and fossil contents alternate throughout the whole series, that I give the following details of it:—

Section of Strata seen in the cliffs to the east of Pittenweem.

	ft.	in.
1. Red Sandstone	40	0
2. Grey Shale with sandstone bands above and ironstone bands and nodules below. Fragmentary remains of small Ganoid fishes, and *Leperditia Okeni*, var. *scotoburdigalensis*	16	0
3. Black Shale with ironstone bands. Ganoid scales, *Lep. scotoburdigalensis*, *Beyrichia subarcuata*, and *Lepidodendron*	2	0
4. Coal †	2	0
5. Grey Shale or Fireclay. Stigmarian roots and rootlets, and *Lepidodendron*	1	6
6. Sandstone, flaggy, and with partings of shale above. Stigmarian roots (large) and rootlets and fragments of large stems	11	0
7. Grey Shale, sandy above, with bands of ironstone nodules, and two thin beds of crinoidal limestone. Species of *Orthoceras*, *Nautilus*, *Loxonema*, *Macrocheilus*, *Leda*, *Schizodus*, *Discina*, *Productus*, *Spiriferina*, *Bairdia*, *Beyrichia*, *Actinocrinus*, *Poteriocrinus*, *Archæocidaris*, *Stenopora*, plants, &c., as per list	20	0
8. Coal †	1	0
9. Grey Shale. Stigmarian rootlets	0	6
10. Sandstone. Stigmarian rootlets	20	0
11. Grey Shale and flaggy beds	5	0
12. Grey Shale with ironstone bands. *Myalina*, *Sphenopteris affinis*, and other obscure remains of plants	15	0
13. Black, carbonaceous Shale, laminated. Layers of *Myalina modioliformis* and coprolites	0	6

* Dr. Traquair drew my attention to this bed.

† These two coals have evidently been worked in former times, for both are now represented by "waste" rather than coal; and one of the old shafts may be seen in section, as exposed by a fall of the cliff.

	ft.	in.
14. Band of Ironstone and black shale. *Leaia Leidyi, Carbonia* sp., and other Entomostraca	0	4
15. Band of very hard, impure Limestone, full of *Myalina*, along with species as per list of zone 6 ...	0	4
16. Black Shale, laminated. A few *Myalinæ*, fish-remains, *Lepidodendron*, and *Lepidostrobus*	0	10
17. Grey Shale with ironstone nodules	2	0
18. Black, shivery, highly-carbonaceous Shale	1	6
19. Ironstone	0	6
20. Light grey Fireclay, with ironstone nodules...............	8	0
21. Light grey, sandy shale, with a 3-inch band of calcareous ironstone, full of a small bivalve, possibly a dwarfed form of *Pleurophorus elegans*, and stray examples of *Littorina scotoburdigalensis* and plant-remains.........	7	0
22. Grey Shale, with an ironstone band full of *Leperditia Okeni*, var. *scotoburdigalensis*	3	0
23. Hard grey Limestone. *Littorina scotoburdigalensis, L. bilineata, Kirkbya spiralis, Leperditia Okeni*	0	9
24. Black, laminated Shale and blackband ironstone. Ganoid scales, coprolites, and *Lepidodendron*.........	1	9
25. White Sandstone	3	0
26. Light grey Shale with ironstone bands	4	0
27. Very coarse Coal	1	0
28. Dark Fireclay	1	0

The above strata are seen just to the east of Pittenweem. Beneath them are about 450 feet of measures with no marine beds. In these measures there are more shale and fireclay than sandstone, though the alternations of argillaceous with arenaceous strata are numberless. Nearly all the shales are charged with ironstone bands and nodules, and some of them are highly bituminous. Ten thin coals occur in this part of the section, most of which rest on fireclay with Stigmarian rootlets.

Plant-remains are very generally distributed throughout, though the species are few as before. The remains of *Stigmaria* are common, not only in the fireclays underlying the coals, but in other beds. *Lepidodendron* and *Lepidophyllum* are found in many of the strata, and *Sphenopteris affinis* and *Cyclopteris flabellata* are not rare in a fragmentary state; the latter species has not been found much above the line of 2250 feet. There are also the teeth and scales of small Ganoids at various horizons, often associated with plants; and the carapaces of Ostracod crustaceans are very plentiful in some of the black shales and ironstones. *Leperditia Okeni*, var. *scotoburdigalensis*, is the most prevalent; the other species are *Beyrichia subarcuata*, *Cythere superba*, and *Carbonia subula*.

Below the above measures, and at a depth of over 2800 feet, there comes into section a bed of shale, about ten feet thick, with two bands of calcareous ironstone. This deposit contains the following marine species :—

Fossils of Zone 8, *at* 2815 *feet.*

Orthoceras, sp.
Bellerophon Urii, *Flem.*
—— decussatus, *Flem.*
Macrocheilus acutus, *Sow.*
Murchisonia striatula, *De Kon.*
—— elongata, *Portlock.*
Avicula, sp.
Aviculopecten, sp. nov.
—— sp.
Cypricardia glabrata, *M'Coy.*
Edmondia rudis, *M'Coy.*
Leptodomus costellatus, *M'Coy.*
Myalina, sp.
Schizodus Salteri, *Eth.*
Fenestella tuberculo-carinata, *Eth.*
—— plebeia, *M'Coy.*
—— Morrisii, *M'Coy.*
Archæopora nexilis, *De Kon.*
Synocladia, sp. nov.
Alveolites septosa, *Flem.*
Stenopora tumida, *Phill.*
Crinoids.
Leperditia Okeni, var.
Beyrichia, sp.

The Polyzoa and the Coral, *Stenopora tumida*, are by far the most common fossils of this zone, some of the surfaces of both the shale and the ironstone being covered with their remains. The crinoidal fragments are also very abundant in the ironstones, where most of the shells are also mainly found.

More than 200 feet of strata intervene. The sandstones of this mass are yellow, purple, and grey in colour, finely rippled in places, and often with thick shaly partings. The shales are charged with ironstones chiefly in bands. There are three coals resting on fire-clays, none of them exceeding a few inches in thickness. Stigmarian rootlets prevail in the vicinity of the thin coals, and *Cyclopteris flabellata* is exceedingly common in some of the grey shales. Along with this species are the remains of great numbers of what appear to be fern-stems.

In a bed of tough black shale, at 2956 feet, there occur the scales of *Rhizodus Hibberti*, with the shells of *Spirorbis* attached, the scales of smaller Ganoids, *Carbonia Rankiniana*, *Carpolithes* sp., *Lepidophyllum*, and *Cyclopteris flabellata.*

About 20 feet lower down there is about 30 inches of purple shale containing *Sphenopteris affinis* and *S. dilatata* abundantly and in good preservation.

At over 3000 feet there is a grey limestone (weathering yellow) with shaly partings, and about two feet thick, which I take to be a marine deposit.

Fossils of Zone 9, *at* 3027 *feet.*

Littorina scotoburdigalensis, *Eth.*
Naticopsis ? sp.
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
—— ——, var. elongata, *J. & K.*
Spirorbis carbonarius, *Murch.*
Teeth and scales of small Ganoids.
Coprolites of Rhizodus (?).
Lepidostrobus, sp.

The *Littorinæ* are very abundant on certain surfaces of this bed; and the action of the sea and the weather brings them out beautifully in relief. *Leperditia Okeni*, var. *scotoburdigalensis*, is even more abundant than the univalve, for much of the rock is formed of its carapaces. This small group of species is not so decidedly marine in its features as the last. I consider it marine, principally on account of the prevalence of *Littorina scotoburdigalensis*, which in other localities occurs along with *Myalina modioliformis*, *Schizodus Salteri*, *Orthoceras*, and other fossils.

Between the last-named limestone and the next marine bed the measures are disturbed, and there are probably some strata wanting in the section visible. Rather over 100 feet of measures are seen, consisting of alternations of yellow and purple, irregularly bedded, and ripple-marked sandstones, with grey shales and fireclays. Three thin coals are included in this mass of strata. *Cyclopteris flabellata* and Stigmarian roots and rootlets are the prevailing fossils. In the roofs of one of the coals are the stools and flattened trunks of large trees; and in another are smaller stems coated with *Spirorbis*.

From beneath these disturbed strata there rises a thin bed of limestone, one foot thick, containing a decidedly marine group of species. The limestone is grey (weathering yellow) and very hard. Beneath it, separated by 8 inches of black shale, containing plants and the scales of small Ganoids, is 3 inches of coal resting on fireclay with rootlets.

Fossils of Zone 10, *at* 3130 *feet.*

Bellerophon decussatus, *Flem.*
Macrocheilus striatulus, sp. nov.
Murchisonia striatula, *De Kon.*
Naticopsis ?, sp.
Cypricardia, sp.
Leda attenuata, *Flem.*
Myalina sublamellosa, *Eth.*
Modiola divisa, *M'Coy.*
Avicula recta ?, *M'Coy.*
Sanguinolites abdensis, *Eth.*
Bairdia subelongata, *J. & K.*
Beyrichia crinita, *J. & K.*
—— subarcuata, *Jones.*
Cythere superba, *J. & K.*
Leperditia Okeni, *Münst.*
Remains of plants.

Sanguinolites abdensis is abundant in this bed, and one layer is full of its broken shells. The curious fringed *Beyrichia*, *B. crinita*, is also a common fossil, though not seen at any other horizon.

This limestone is seen a little to the west of Billow Ness. Four miles further east, at the Pans, west of Crail, it reappears, with the black shale, coal, and fireclay underlying it as before. The shale contains the teeth of *Diplodus* and *Ctenoptychius*, besides the scales of small Ganoids. And the limestone has yielded the following species:—*Orthoceras* sp., *Bellerophon decussatus*, *Macrocheilus striatulus*, *Murchisonia striatula*, *M. quadricarinata*, *Leda attenuata*, *Modiola divisa*, *Myalina crassa*?, *Nucula* sp., *Sanguinolites abdensis*, *Beyrichia* sp., *Leperditia Okeni*, and *Spirorbis* sp.

About 100 feet of measures intervene. They consist of purple and greyish sandstones alternating with grey and purple shales, enclosing one 6-inch coal and a bed of limestone about 1 foot thick. The only fossils found in the latter are *Lepidodendron* and some other plants (obscure), the scales of small Ganoids, and coprolites. In a grey shale about 5 feet above the limestone (3168 feet) there are casts of a shell like *Anthracosia* along with Stigmarian rootlets; and in a bed of red shale below the limestone (3192 feet) there occur stray and imperfect examples of a shell resembling *Myalina*, associated with *Spirorbis*, the scales of small Ganoids, an Entomostracan, and *Sphenopteris affinis*.

Lower still, at 3230 feet, in a grey shale overlying another bed of limestone, *Myalina modioliformis* appears in great numbers. Along with it, and in the limestone, are the following species:—

Fossils of Zone 11, *at* 3230 *feet* (just to the east of the Target, Billow Ness).

Myalina modioliformis, *Brown.*
Beyrichia subarcuata, *Jones.*
Carbonia fabulina, *J. & K.*
—— subula, *J. & K.*
—— Rankiniana? or bairdioides?, *J. & K.*
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
Lepidodendron and Lepidostrobus.

50 feet of measures intervene, which mainly consist of purplish, grey, and yellow false-bedded sandstone in a thick stratum. An 8-inch coal lies a few feet below the limestone.

Then at 3280 feet comes in a 2-feet bed of limestone, hard, grey (weathering yellow), and shaly at the top, with a laminated shale above, and a black shale, thin coal, and fireclay below. In these deposits occur the following fossils:—

Fossils of Zone 12, *at* 3280 *feet.*

In the upper shale:—

Lingula squamiformis, *Phill.*
Beyrichia subarcuata, *Jones.*
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
Scales of small Ganoids.
Coprolites (Rhizodus).
Sphenopteris affinis (rare).

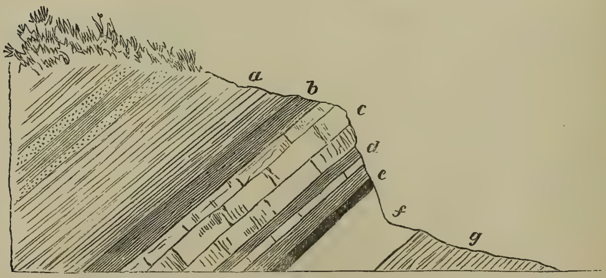
In the limestone:—

Littorina scotoburdigalensis, *Eth.*
Dithyrocaris (tooth).
Beyrichia subarcuata, *Jones.*
Cythere?, sp.
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
—— Okeni, var. attenuata, *J. & K.*
Spirorbis, sp., attached to plants.

In the shale below:—

Lingula squamiformis, *Phill.*
Myalina modioliformis, *Brown.*
Schizodus Salteri, *Eth.*
Beyrichia subarcuata, *Jones.*
Kirkbya spiralis, *J. & K.*
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
Scales of small Ganoids.

Fig. 1.—*Section of strata at Zone* 12.



a. Grey shale; *b.* Tough dark shale with *Lingula*, &c.; *c.* Limestone; *d.* Band of *Schizodus* in black shale; *e.* 3-inch seam of coal; *f.* Fireclay with Stigmarian rootlets; *g.* Grey shale.

Fig. 1 shows the sequence of the beds forming this zone, which is only one example of several of the immediate succession of marine conditions after coal-growths.

The same series of beds with the same fossil contents is again seen on the coast two miles or more to the east, near Caiplie.

Over 50 feet of purple and yellow sandstone and grey shale intervene*, and then *Myalina modioliformis* is again found abundantly in a thick bed of shale enclosing ironstone nodules above and three or four bands of ironstone below.

Fossils of Zone 13, *at* 3338 *feet.*

Littorina scotoburdigalensis, *Eth.*
Myalina modiolifornis, *Brown.*
Beyrichia subarcuata, *Jones.*
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
Nematoptychius Greenockii, *Ag.*
Coprolites (Rhizodus?).

Fifty feet of measures intervene, chiefly purple and yellowish sandstone, forming the point known as Billow Ness. Immediately below the sandstone there is a bed of red and grey shale with thin layers of red ironstone, full of *Myalina* and Entomostraca.

Fossils of Zone 14, *at* 3400 *feet* †.

Littorina scotoburdigalensis, *Eth.*
Myalina modioliformis, *Brown.*
Pleurophorus elegans, sp. nov.
Cythere superba, *J. & K.*
Coprolites (Rhizodus?).

A bed of limestone lies below the shale. The only fossils found in it are coprolites, scales of small Ganoids, *Lep. scotoburdigalensis*, *Lepidodendron*, and *Lepidophyllum*.

Underlying these strata follow nearly 20 feet of fireclay and shale with several bands of coarse coal, which are full of vegetable remains, including the stools and flattened trunks of trees. Other measures come in beneath, making a thickness of nearly 50 feet before *Myalina modioliformis* is met with again, in a bed of grey shale and ironstone bands.

Fossils of Zone 15, *at* 3450 *feet* †.

Myalina modioliformis, *Brown*, small and thin-shelled.
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
Spirorbis, sp., attached to the Myalina.
Lepidophyllum, and fragments of other plants.

Twenty feet of yellow and purple sandstone and shale, with a coal about a foot thick, intervene. Many remains of *Lepidodendron*, *Calamites*, and other plants are found near the top of the sandstone. Beneath these beds there is a limestone, 6 inches thick, containing *Myalina* sp., and under it a thin bed of marl with Stigmarian rootlets.

Fossils of Zone 16, *at* 3475 *feet* †.

Myalina, sp.

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* Since the reading of this paper a thin limestone has been exposed between tide-marks, about 20 feet below the strata forming zone 12. The following species occur in it:—*Littorina scotoburdigalensis*, *Leperditia Okeni*, vars. *extuberata* and *attenuata*, *Spirorbis carbonarius*, Ganoid scales, and traces of plants.

† Zones 14, 15, and 16 are seen on the east side of Billow Ness.

Between the last-named limestone and the next marine bed I estimate a thickness of 120 feet of measures, most of which are so much denuded as to be hidden from view by sand. At the west end of Anstruther Wester there is a limestone 15 inches thick, containing *Myalina modioliformis.* The limestone is grey (weathering yellow), hard, and with shaly partings. In it and the underlying shale are the following species:—

Fossils of Zone 17, *at* 3600 *feet.*

Myalina modioliformis, *Brown.*
Carbonia subula, *J. & K.*
Spirorbis, sp. (large).
Teeth, scales, and bones of small Ganoids.
Fragments of carbonized wood.

200 feet of measures intervene, including thick irregularly bedded sandstones, white, reddish, and yellow in colour, and shales and fireclays with ironstone and sandstone bands. There are no coals, though Stigmarian rootlets are plentiful enough in the fireclays. At 3750 feet there is a limestone, but its only fossils are the scales of small Ganoids, Coprolites, *Leperditia Okeni*, var. *scotoburdigalensis*, *Beyrichia*, *Cyclopteris flabellata* (large), *Sphenopteris affinis*, fern-stems, and *Carpolithes sulcata.*

Then is reached the lowest limestone in which I have seen marine fossils. This bed is about a foot thick, hard, and grey (weathering red on the surface); it is seen near high-water mark at Anstruther Wester, a little to the west of the Dreel Burn.

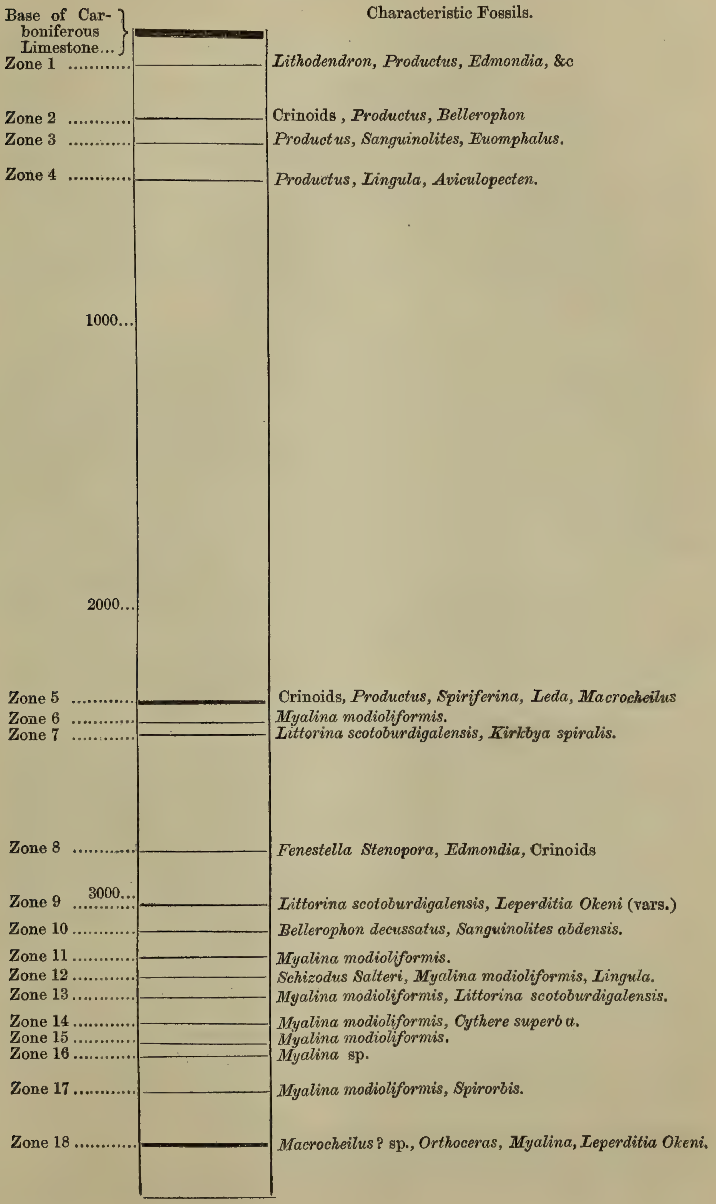
Fossils of Zone 18, *at* 3800 *feet.*

Orthoceras, sp.
Macrocheilus striatulus, sp. nov.
Myalina modioliformis, *Brown.*
Bairdia nitida, *J. & K.*
Beyrichia subarcuata, *Jones.*
Leperditia Okeni, var.
Spirorbis, sp.

About 130 feet of measures crop out below this limestone before the dip is reversed. They consist of grey and yellow sandstones and grey shales, with a thin band (6 inches) of limestone and a 4-inch layer of coal. In them occur the scales and plates of small Ganoid fishes, *Beyrichia subarcuata*, *Leperditia Okeni*, var. *attenuata*, *Carbonia fabulina*, *C. Rankiniana*, *Spirorbis* attached to plants and free, *Sphenopteris affinis*, and *Stigmaria.* The *Beyrichia* and a var. of *Lep. Okeni* are found in the lowest shales, just to the west of Anstruther Harbour.

The measures about Anstruther Harbour are the lowest Calciferous Sandstones that I have seen on the Fife coast. From Anstruther to Crail the dip is reversed, and the strata seen at Anstruther Wester, and from there to the west of Billow Ness, again appear, though not so clearly and consecutively as before. Beyond Crail, and on to Fife Ness, and then westward by Kingsbarns, Babbet Ness, Pitmilly Burn, and Borehills, the strata continue rolling, apparently in a portion of the series equivalent to that seen east and west of Billow Ness. Nearer St. Andrews higher beds appear to come up; for to the east of the Rock and Spindle there is a thin crinoidal limestone and associated shale, containing a similar suite of marine fossils as that found in the Encrinite-bed at Pittenweem.

Fig. 2.—*Diagrammatic Vertical Section of the Calciferous Sandstones from the west of Pittenweem to Anstruther, showing the position of the Zones of Marine Fossils.* (Scale 666 feet to 1 inch.)



It has been remarked by the Rev. Thomas Brown that the marine beds of the lower part of the Calciferous Sandstones increase in thickness and number as they are traced further east *. This is very clearly shown in a section that is exposed between tide-marks at Randerstone, south of Kingsbarns. This section forms a synclinal, most of the beds cropping out east and west of a central trough which is nearly opposite to Randerstone farmhouse. The thickness of strata exposed does not much exceed 400 feet; but it includes twelve limestones, the majority of which contain marine fossils. The prevalence of *Schizodus Salteri* and *Myalina modioliformis* in several of the beds, as well as the contiguity of the limestones, appears to indicate a position for these strata equivalent to the measures between 3200 and 3600 feet of the Pittenweem and Anstruther section. As this outcrop of strata is the most marine bit of the lower portion of the Calciferous Sandstones that I have met with in Fife; it is noticed in detail as the

Randerstone Section.

In the highest limestone at Randerstone I have found only a species of *Spirorbis*. This limestone is taken to be 3155 feet below the base of the Carboniferous Limestone series, the figures being arrived at by looking upon limestone No. 5 of this section as equivalent to the band of *Schizodus Salteri* (Zone 12) of the Pittenween and Anstruther series of strata.

Thirteen feet of strata intervene between this limestone and the next beneath.

Limestone No. 2 (3170) is hard, grey, and two feet thick. From it, and the shale and ironstone bands immediately above and below, there have been obtained the following species:—

Myalina modioliformis, *Brown.*
Carbonia subula, *J. & K.*
Leperditia Okeni, var. scotoburdigalensis, *Hibbert.*
Coprolites of Rhizodus ?

A thick mass of sandstone intervenes.

Limestone No. 3 (3200 feet) is a shell-bed, fully four feet thick, almost entirely composed of the shells of *Myalina modioliformis.* In this bed, as well as in the overlying shale, and in the thick shale and ironstones below, the *Myalinæ* are large, though thicker-shelled in the limestone and ironstones than in the shale. *Spirorbis* encrusts the shells in some places; and here and there in the limestone are drifted fragments of carbonized wood (*Dadoxylon*) showing structure †.

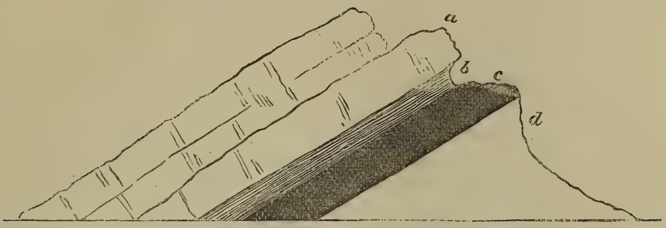
Littorina scotoburdigalensis, *Eth.*
Myalina modioliformis, *Brown.*
Carbonia subula, *J. & K.*
Spirorbis.
Fragments of wood (*Dadoxylon*).

A thick bed of *Myalina*, probably the same as this, is seen to the east of Kingsbarns Harbour; and to the east of the Rock and Spindle, a limestone 5 feet thick, full of *Myalina*, with a seam of coal below it (both altered by heat), is exposed between tide-marks, as shown in the accompanying woodcut (fig. 3).

* Trans. Roy. Soc. Edinb. vol. xxii. p. 399.

† The eastern outcrop of this bed is seen just below the sandstone reef to the west of Old Haiks.

Fig. 3.—*Section of* Myalina-*bed and coal, near the Rock and Spindle.*



a. 5 feet of *Myalina* limestone; *b.* 9 inches of black shale with fish-scales; *c.* 16 inches of coarse burnt coal; *d.* Fireclay with Stigmarian rootlets.

Limestone No. 3*a* is 10 feet or more below; it is 2 feet thick, and rests upon a foot of good cherry coal. It contains the following species:—

Ctenacanthus, sp.
Eurynotus crenatus, *Ag.* (scales).
Palatal teeth.
Murchisonia, sp.
Schizodus Salteri, *Eth.*
A thin Anthracomya-like shell.
Leperditia Okeni, var. attenuata, *J. & K.*
—— ——, var. extuberata, *J. & K.*
—— ——, var. scotoburdigalensis, *Hib.*
Kirkbya spiralis, *J. & K.*
Plant-remains.

Another thick sandstone intervenes.

Limestone No. 4 (3343 feet) is about 11 inches thick, shaly at the top, and rests on a thin seam of coal. Its fossils are:—

Myalina modioliformis, *Brown.*
Kirkbya spiralis, *J. & K.*
Leperditia Okeni, var. scotoburdigalensis, *Hib.*
Leperditia Okeni, var. attenuata, *J. & K.*
Spirorbis.
Fish-spine, Ctenacanthus?
Lepidodendron, sp.

Shale, black in places and with plant-remains, and sandstone intervene.

Limestone No. 5 (3380 feet) is grey, weathering yellow and red on the surface, hard, subcrystalline, and 2 feet 9 inches thick, inclusive of a centre band of shale. Its upper surface is thickly strewed with the shells of *Schizodus Salteri*, along with rarer specimens of *Orthoceras cylindraceum*?, *Aviculopecten granosus*, &c. The following is a list of its fossils:—

Orthoceras cylindraceum?, *Flem.*
Littorina scotoburdigalensis, *Eth.*
Loxonema scalaroidea, *Phill.*
Macrocheilus striatulus, sp. nov.
Murchisonia quadricarinata, *M'Coy.*
Naticopsis plicistria, *Phill.*
Aviculopecten granosus, *Phill.*
Myalina modioliformis, *Brown.*
Nucula lineata, *Phill.*
Sanguinolites abdensis, *Eth.*
—— subplicatus, sp. nov.
Schizodus Salteri, *Eth.*
Lingula mytiloides, *Sow.*
Bairdia siliquoides, *J. & K.*
Beyrichia subarcuata, *Jones.*
—— ——, var.*
Cythere Jonesiana, *Kirkby.*
—— æqualis, *J. & K.*
Kirkbya spiralis, *J. & K.*
Leperditia Okeni, *Münst.*
Spirorbis globosus, *M'Coy.*
—— helicteres, *Salter.*
—— sp.
Rhizodus Hibberti, *Ag.*
Lepidophyllum.
Wood in drifted fragments.

* This form differs somewhat from typical specimens of *B. subarcuata* in the trilobate character of the valves, and, possibly, when thoroughly known, may prove to be distinct from that species.

Fig. 4 represents a section of this bed, explanatory (with the details that follow) of the distribution of the above fossils.

Commencing at the base, the grey shale and sandstone band *a* contains large Stigmarian roots and rootlets, *Sphenopteris affinis* and other plants, the scales and bones of small Ganoid fishes, teeth of *Diplodus*, and carapace-valves of *Leperditia Okeni*, var., and *Beyrichia subarcuata.* This deposit evidently indicates an area on which grew large trees, the roots of which only remain.

The lower leaf of limestone, *b*, is a foot thick, and very siliceous below. The inferior portion of it is full of fragments of stems and carbonized wood, all apparently drifted, and many incrusted with *Spirorbis.* A few specimens of *Myalina modioliformis* are seen here, and occasionally large teeth of *Rhizodus Hibberti.*

In the upper portion of the same leaf of limestone the *Myalina* becomes more numerous, and the fragments of wood less so than below.

The nine inches of dark grey shale, *c*, that separates the limestone into two leaves contains many individuals of *Leperditia Okeni,* var., and *Beyrichia subarcuata*, var., with a few of *Myalina modioliformis*, and the remains of *Lepidophyllum* and other plants.

The lower half of the limestone, *d*, is filled with *Myalina modioliformis.* Along with it are found *Nucula lineata*, *Littorina scotoburdigalensis*, *Leperditia Okeni*, and *Spirorbis.* Many of the *Myalinæ* are in single valves, and still more of them are fragments, worn and rounded, the thick umbonal bits being very common. The *Spirorbes* are found both attached to the *Myalina* and free.

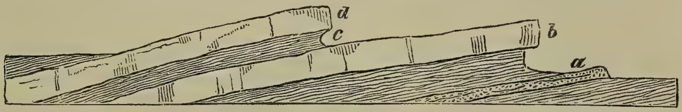
Higher, but not including the top portion, the *Myalina* is associated with *Schizodus Salteri* and *Sanguinolites* sp., *Littorina scotoburdigalensis*, *Macrocheilus striatulus*, *Leperditia Okeni*, and *Spirorbis* in abundance. The shells of the *Sanguinolites* form a thin layer in this part of the bed. The other bivalves occur mainly as single valves or as fragments, though not so much worn as immediately below. *Spirorbis* incrusts all these shells, the interiors of the *Schizodus* being often beautifully covered with it.

In the top two inches of the limestone there are none of the *Myalina, Schizodus Salteri* taking its place as the prevailing species. With it occur *Orthoceras* sp., *Murchisonia quadricarinata*, *Naticopsis plicistria*, *Loxonema scalaroidea*, *Macrocheilus striatulus*, *Aviculopecten granosus*, *Sanguinolites abdensis*, *S. subplicatus*, *Nucula lineata*, *Lingula mytiloides*, *Cythere Jonesiana*, *C. æqualis*, *Leperditia Okeni*, *L. Okeni*, var., *Beyrichia subarcuata*, *B. subarcuata*, var., *Kirkbya spiralis*, *Spirorbis globosus*, *S. helicteres.* The valves of the lamellibranchs are mostly detached, but not much worn, the hinge-teeth being sharp and well preserved in carefully extracted specimens.

The above details of the distribution of fossils in this bed show changes from an area of tree-growths towards marine conditions of increasing intensity. Other marine beds in the Calciferous Sandstones show pretty much the same sort of progression; but in many cases the advance towards marine conditions does not reach further than the introduction of *Myalina modioliformis.*

At the outcrop of this bed the measures lie rather flat, so that a considerable area of it is exposed between tide-marks*. Occasionally, when the rock has been swept clean of weeds, its *Schizodus*-covered surface affords a most interesting sight, though one suggestive rather of a Permian state of things than of early Carboniferous—an idea which is only strengthened on finding a species of *Myalina* just as abundant in the body of the rock; for in the Magnesian Limestone of the North of England the two most common fossils in the upper beds, and those, in fact, which last appear, are *Schizodus dubius* and *Myalina Hausmanni*.

Fig. 4.—*Section of Limestone No. 5, Randerstone.*



a. Shale and sandstone band with *Stigmaria, Diplodus*, and Ostracoda; *b.* 1 foot of siliceous limestone with drift wood, *Rhizodus*, and *Myalina*; *c.* 9 inches of shale with Ostracoda and *Lepidophyllum*; *d.* 1 foot of limestone full of *Myalina, Schizodus, Orthoceras*, &c.

Forty feet of shale and sandstone intervene; the latter is false-bedded and ripple-marked. In one place the shale is black and coaly, with fireclay beneath full of rootlets. More *Stigmariæ* are found in these strata, along with *Calamites* sp., *Cyclopteris flabellata*, the scales of small Ganoids, and Entomostraca.

Limestone No. 6 (3326 feet) is about two feet thick, hard, compact, and grey in colour (also weathering grey). It is formed of three or four leaves; and it is chiefly on the weathered surfaces of these that the following fossils have been found:—

Nautilus planotergatus ?, *M'Coy.*
Orthoceras, sp.
Loxonema scalaroidea, *Phill.*
Murchisonia quadricarinata, *M'Coy.*
Naticopsis, sp.
Aviculopecten granosus, *Phill.*
Leda, sp.
Myalina modioliformis, *Brown.*
Nucula lineata, *Phill.*
Sanguinolites abdensis, *Eth.*
Schizodus Salteri, *Eth.*
Sedgwickia gigantea, *M'Coy.*
Lingula mytiloides, *Sow.*
Stenopora tumida, *Phill.*
Spirorbis helicteres, *Salter.*
Leperditia Okeni, *Münst.*
Beyrichia subarcuata, *Jones.*
Ganoid scales resembling those of *Megalichthys.*

Murchisonia quadricarinata is the most characteristic fossil of this limestone; it is found on the weathered surfaces beautifully preserved, and occasionally in great numbers. *Stenopora tumida* and *Leperditia Okeni* are also very abundant. *Schizodus Salteri* forms a thin layer of shells on top of the limestone. The shell referred to *Sedgwickia gigantea* has only been found in this bed; some of the specimens exceed three inches in width. The bottom leaf of the limestone is entirely composed of a *Spirorbis*, apparently identical with *S. helicteres.*

* This bed shelves up to the point to the east of the road to Randerstone.

More than thirty feet of shale and sandstone intervene, in which fossils have not been observed.

Limestone No. 7 (3360 feet) is of irregular thickness; usually about 15 inches. Its upper surface is covered with shells of *Myalina*, some of which are large and more like *M. crassa* than the common species (though less massive). Though these shells are the prevailing fossils of the bed, one of the most characteristic species is a large thick-shelled *Bellerophon*, which comes very near to *B. costatus*. Another species of frequent occurrence is *Naticopsis plicistria*, little coteries of them often being found within the apertures of the Bellerophons. *Rhynchonella pleurodon* is found abundantly at one horizon of the bed. The last-named species, along with *Lingula mytiloides* and *L. squamiformis*, are the only Brachiopods that have been met with so low in the Calciferous Sandstones.

Orthoceras, sp.
Bellerophon costatus, *Sow.*
—— decussatus, *Flem.*
Loxonema scalaroidea, *Phill.*
Macrocheilus acutus, *Sow.*
Murchisonia quadricarinata, *M'Coy.*
—— striatula, *De Kon.*
Naticopsis plicistria, *Phill.*
Aviculopecten granosus, *Phill.*
Leda, sp.
Myalina crassa ?, *Flem.*
—— modioliformis, *Brown.*
Nucula lineata, *Phill.*
Schizodus Salteri, *Eth.*
Rhynchonella pleurodon, *Phill.*
Diastopora megastoma, *M'Coy.*
Stenopora tumida, *Phill.*
Beyrichia subarcuata, *Jones.*
Leperditia Okeni, *Münst.*

Within the next twenty feet of shale there are three thin bands of *Myalina modioliformis*. The only other fossils found in these bands are the scales of small Ganoids, *Leperditia Okeni*, var. *scotoburdigalensis*, *Spirorbis* sp., and fragments of carbonized wood. A few feet lower there is an irregular bed of arenaceous ironstone, full of carbonaceous matter and the fragmentary remains of fishes, chiefly of *Rhizodus Hibberti*. Then follow more shales and thin sandstones, with *Sphenopteris affinis*, *Lepidophyllum*, seed-vessels? and other plant-remains, *Spirorbis* sp., and Ganoid scales.

No. 8 Limestone (3413 feet) is nineteen inches thick, hard, grey in colour, and weathering red. Its characteristic fossils are Ostracoda, 13 species of which have been found in it. The other fossils are most of them small, as though dwarfed:—

Orthoceras, sp.
Littorina scotoburdigalensis, *Eth.*
Macrocheilus striatulus, sp. nov.
Murchisonia quadricarinata, *M'Coy.*
Avicula recta?, *M'Coy.*
Myalina modioliformis, *Brown.*
Schizodus Salteri, *Eth.*
Beyrichia subarcuata, *Jones.*
—— ——, var.
Bairdia plebeia, *Reuss.*
—— Hisingeri, *Münst.*
—— siliquoides, *Jones & Kirkby.*
—— præcisa, *J. & K.*
Bairdia subcylindrica ?, *Münst.*
Cythere Jonesiana, *Kirkby.*
—— intermedia, *Münst.*
—— æqualis, *J. & K.*
—— cypridiformis, *J. & K.*
Kirkbya plicata, *J. & K.*
—— spiralis, *J. & K.*
Leperditia Okeni.
—— ——, var. extuberata, *J. & K.*
Archæocidaris, small spine of.
Spirorbis, sp.
Teeth and scales of Ganoid fishes.

100 feet of measures intervene, chiefly sandstones. In the more argillaceous beds are found *Sphenopteris affinis*, *Lepidodendron* sp.,

scales and teeth of small Ganoid fishes, and *Leperditia Okeni*, var. *scotoburdigalensis*.

Limestone No. 9 (3514 feet) is a curious concretionary bed, about nine inches thick, with a rough irregular under surface. It weathers red and yellow, is hard, and is largely composed of concentric concretions of various sizes *. It contains myriads of *Leperditia Okeni*, var., along with *Spirorbis* sp., small Ganoid scales, fragments of wood, and Stigmarian roots and rootlets.

A few feet of sandstone and shale with *Sphenopteris affinis* intervene.

Limestone No. 10 (3525 feet) is very hard and crystalline, weathers red, and is of variable thickness, averaging about a foot. In an inch of shale immediately above there occur a few examples of *Myalina modioliformis*, the teeth and scales of small Ganoids, *Leperditia Okeni*, var. *attenuata*, and *Sphenopteris affinis*. The limestone itself is, in some places, full of the single valves and shell-débris of *Pleurophorus elegans*, a bivalve which, though so abundant here, has only been observed in two other localities. Along with the latter species are numbers of *Littorina scotoburdigalensis* (well preserved, and in some cases showing traces of transverse bands of colour) and a variety of *Leperditia Okeni*.

Pleurophorus elegans, sp. nov.
Littorina scotoburdigalensis, *Eth.*
Leperditia Okeni, var. attenuata, *J. & K.*

Limestone No. 11 (3546 feet) crops out from beneath twenty feet of marl, shale, and sandstone, without fossils. It is likewise an irregular bed, in three or more leaves, with partings of shale. It weathers red, and is about two feet thick. The only fossils found in it are fish-remains, belonging to *Rhizodus ornatus*, Traquair, and other species. The plates and bones of the former fish are chiefly in the partings of shale, from which they are to be picked up, detached by the action of the sea.

In the marl beneath the limestone occur *Spirorbis helicteres* and a species of *Kirkbya*.

Thirty feet of unfossiliferous strata are seen beneath the last limestone, and then the crown of an anticline is reached, beyond which the dip is reversed. A repetition of the beds described, however, is not clearly seen, owing to the disturbance of the strata by faults. Various shell-beds appear, full of *Myalina*, which probably represent some of those I have noticed; and beyond the faulted ground, a little to the east of the caves under Randerstone Castle, where the strata dip regularly to the east, there is a marine limestone that requires description, though its exact position in relation to the foregoing section is scarcely to be determined.

This limestone is about 15 inches in thickness, and is intercalated between beds of sandstone. It is grey in colour, hard, and has shaly partings below. At its base, and forming part of the same bed palæontologically, come 4 inches of very hard, yellow, calcareous sandstone, which is soldered on, as it were, to an 8-feet bed

* This rock reminds me of some of the botryoidal and globular forms of the Upper Magnesian Limestone of Sunderland.

of white, siliceous, false-bedded sandstone. This band of calcareous sandstone contains numbers of specimens of an *Orthoceras* (10 inches in length), along with others of *Nautilus*, *Bellerophon*, *Macrocheilus*, and other marine forms, mixed with the roots and rootlets of *Stigmaria*. In the limestone, and particularly on its weathered surface-planes, are strewed multitudes of various species of *Murchisonia*, *Macrocheilus*, *Loxonema*, *Trochus*, and other univalves, as well as of species of Lamellibranchs, along with occasional remains of *Lepidodendron* and much comminuted vegetable matter. The following is a list of the species :—

Nautilus, sp.
Orthoceras cylindraceum, *Flem.*
Bellerophon costatus, *Sow.*
Euomphalus neglectus, *M'Coy.*
Lacuna antiqua, *M'Coy.*
Loxonema scalaroidea, *Phill.*
Macrocheilus fusiformis, *Sow.*
—— acutus, *Sow.*
—— imbricatus, *Sow.*
—— striatulus, sp. nov.
Murchisonia quadricarinata, *M'Coy.*
—— angulata, *Phill.*
—— striatula, *De Kon.*
Naticopsis elliptica, *Phill.*
Trochus serrilimba, *Phill.*
—— sp.
Cypricardia bicosta, sp. nov.
Lithodomus dactyloides, *M'Coy.*
Modiola divisa, *M'Coy.*
Nucula lineata, *Phill.*
Sanguinolites abdensis, *Eth.*
Schizodus Salteri, *Eth.*
—— axiniformis, *Phill.*
Beyrichia subarcuata, *Jones.*
Kirkbya plicata, *Jones & Kirkby.*
Leperditia Okeni, *Münst.*
Archæocidaris, small spine.
Spirorbis, sp.
Cladochonus, sp.
Tooth and scales of a small Ganoid fish.
Pœcilodus obliquus, *Ag.*
Lepidodendron, sp.
Stigmarian roots and rootlets.
Plant-remains, obscure.

Twelve of the above species have not occurred elsewhere in the Lower Carboniferous strata of Fife; and I do not know of a deposit in the same series where Gasteropods are such characteristic fossils.

Near to high-water mark the limestone runs out, or, rather, passes into a grey shale with sandstone bands without fossils. Towards low-water mark it continues, but its marine shells disappear, and the only fossils found in it are Entomostraca (*Leperditia Okeni*, var. *attenuata*, and *Kirkbya*) and traces of Ganoid fishes and plants.

Other marine beds appear at various points of the coast; but they are nearly all recurrences of those already described, containing the same species of fossils, and they never present so continued a sequence as in either of the foregoing sections.

Perhaps the only other bed that need be noticed (and it may or may not be marine) is a thin calcareous sandstone, at Kilrenny Mill, east of Cellardyke, which is full of a bivalve shell, referred to *Anthracosia* by Mr. Salter. Along with the *Anthracosia* are found *Littorina scotoburdigalensis*, *Lepidodendron* sp., with the twigs attached in some cases, and as drifted stems covered with *Spirorbis* in others.

The same bed (apparently) again comes up at Kilminning, east of Crail, with the *Anthracosia* in still greater profusion. *Spirorbis* is here attached to the shells, both on the inside and outside of the valves. *Leperditia Okeni*, var. *extuberata*, also occurs.

The same *Anthracosia* is found sparingly in a shale at Billow Ness, though its position (3168 feet) in the series at that place appears to be considerably higher than at Kilrenny Mill.

Observations.

The thickness of strata in the two sections described, and the distance of the various marine beds from the base of the Carboniferous Limestone, are obtained from a careful and detailed examination of the rocks, bed by bed. Still it should be observed that the amount of strata between the different marine zones must of course be taken as close approximations only; for most of the beds, particularly the sandstones, are subject to such rapid alterations of thickness that no two sections taken twenty yards apart are ever exactly alike.

In the group of marine beds at the top of the series that are seen between St. Monans and Pittenweem, the species are all common to the Carboniferous Limestone, with one exception, *Sanguinolites abdenis.* The only difference which they present, when compared with the fauna of the latter rock-group, consists of the comparative abundance of Lamellibranchs, the scarcity of Brachiopods, and the almost entire absence of corals, excepting the highest limestone (zone 1).

In the Encrinite-bed (zone 5), which is the next marine zone, though separated from those above by nearly 1800 feet of strata, the species with scarcely an exception also all range up into the overlying series. It was this fact that caused Mr. Brown to propose to group the measures from the Encrinite-bed upwards with the Carboniferous Limestone.

It is not, in fact, until we reach the strata below zone 5 that much difference is to be observed in the character of the marine fauna; and even then, if we take the list of species merely, more than four fifths of them are found to pass up into the Carboniferous Limestone. But among the few species peculiar to the series are one or two that occur so often and so abundantly as to mark these lower measures with special palæontological features. These are the prevalence of the Lamellibranchs, *Myalina modioliformis* and *Schizodus Salteri*, the former shell being more especially characteristic, as the preceding portion of this paper will have made evident. Among other species characteristic, though in a less degree, are *Littorina scotoburdigalensis*, *Macrocheilus? striatulus*, and an *Orthoceras* allied to *O. cylindraceum*. As a negative character of some value, there is the remarkable paucity of Brachiopods and Corals, which here is more noticeable than in the strata above, the former class numbering only three species (*Rhynchonella pleurodon*, *Lingula mytiloides*, and *L. squamiformis*) and the latter two (*Stenopora tumida* and *Alveolites septosus*). Altogether 83 species of marine fossils have occurred to me below the Encrinite-bed. Of these, 15 are confined to the Calciferous Sandstones*, as given in the following list:—

* Not including the species of *Anthracosia*, *Anthracomya*, and *Carbonia*, as well as one or two others of doubtful habits.

L ttorina scotoburdigalensis.
—— bilineata.
Macrocheilus ? striatulus.
Cypricardia bicosta.
Myalina modioliformis.
—— sublamellosa.
Pleurophorus elegans.
Sanguinolites abdensis.
Sanguinolites subplicatus.
Schizodus Salteri*.
Bairdia nitida.
—— præcisa.
Cythere superba.
—— cypridiformis.
Kirkbya spiralis.

The repeated occurrence of bituminous shales and thin limestones full of the carapace-valves of Ostracoda is another palæontological feature strongly characteristic of the Calciferous Sandstones. The species thus occurring are not many in number; *Leperditia Okeni*, var. *scotoburdigalensis*, is the most common form; and following it in abundance are *L. Okeni*, var. *attenuata*, and *Beyrichia subarcuata*. These Ostracods may or may not indicate a marine origin of the beds in question. They are all found occasionally with *Myalina modioliformis*, and the *Leperditiæ* are usually of marine habits; and that is about all that can be said on the matter.

Of equally dubious origin are the numerous beds containing the scales of small Ganoid fishes and the remains of *Spirorbis carbonarius*, which often occur with the Ostracoda, or with plants, and sometimes with *Myalina* and other marine fossils—though when such forms as *Orthoceras* and *Schizodus* come in with the latter, this *Spirorbis* gives place to another representative of the genus, identical with, or allied to, *S. globosus*, M'Coy, and the fish-remains are usually absent.

It will have been observed that the groups or zones of fossils of the preceding sections are not all equally marine. Thus zone 11 of the Pittenweem and Anstruther section, which includes the remains of *Lepidodendron* and *Carbonia*, together with *Myalina modioliformis*, can scarcely be looked upon as of so marine a character as the group above, zone 10, which contains among its species representatives of the genera *Bellerophon*, *Murchisonia*, and *Leda*. The fossils of zone 11 and other kindred groups have been looked upon as marking marine horizons mainly on account of the presence of *M. modioliformis*; and this shell I consider to have been a marine species, because it is repeatedly found associated with *Schizodus Salteri* and other undoubted inhabitants of salt water, and because the other species of *Myalina* known to me appear from the associated fossils to have been of marine habits. Thus—

Myalina sublamellosa, Eth., occurs in the thoroughly marine groups of zones 3 and 10 of the Pittenweem and Anstruther section.

Myalina crassa, Flem., another gregarious species, is found with

* This species is described from a patch of strata, isolated by volcanic ash, near Ardross (Rev. T. Brown in Trans. Royal Soc. Edin. xxii. p. 392), the exact stratigraphical position of which is not very clear. In the Geological Survey Map, sheet 41, these beds are coloured as Carboniferous Limestone, which may possibly be correct; but *Schizodus Salteri* is not known from any other Carboniferous-Limestone locality, and the general character of the strata is as much like the highest portion of the Calciferous Sandstone, as exposed to the east of St. Monans, as any part of the overlying series that I have seen.

the remains of Crinoids, *Aviculopecten* sp., *Trochus biserratus*, and *Naticopsis elliptica* in the Carboniferous Limestones of Cults, Fife.

Myalina Verneuilii, M'Coy, is associated with *Schizodus axiniformis*, *Myacites sulcatus*, *Sanguinolites* sp., and *Lingula squamiformis* in shale at the base of the Carboniferous Limestone series, east of St. Monans, Fife.

And the Permian species *Myalina Hausmanni*, Goldfuss (in which is included *M. squamosa* and *M. septifera* of King), is found in the shell-limestone of Durham and the Lower Limestone of Yorkshire with the marine fossils characteristic of those rocks, though in the highest beds of the Magnesian Limestone, where this species becomes in a measure gregarious, its associates dwindle down, in Durham, to *Schizodus dubius*, *Pleurophorus costatus*, and *Littorina helicina*, and in Yorkshire to *S. dubius* only.

Moreover *Lepidodendron* and other vegetable remains are met with in the Encrinite-bed at Pittenweem, and in the equally unquestionably marine deposit to the east of the caves at Randerstone Castle; so that the presence of such remains with *Myalina modioliformis* scarcely indicates more than that the shell existed within reach of vegetable drift.

Notwithstanding the repeated occurrence of marine beds in the Calciferous Sandstones, the proportion which they contribute to the aggregate thickness of the series is not great. The bulk of the strata (where fossiliferous) contains the remains of plants and of other fossils that cannot with any certainty be classed as marine. The evidences of the prevalence of vegetable life are numerous; and first among these are the number of thin coals.

Altogether I have observed in the Pittenweem and Anstruther section about fifty seams of coal, counting every thing from three inches upwards, and there may be some that have escaped my notice. Most of them are coarse in quality, and the thickest rarely exceeds two feet, the majority being much less. But though not thus of much commercial value, they are nearly all true coal-growths, resting on fireclays charged with *Stigmariæ*. These coals are pretty regularly distributed through all but the lowest 500 feet of strata.

Stigmarian roots and rootlets are met with in many fireclays, shales, and shaly sandstones where there are no overlying coals or traces left of the vegetation which these roots must have originally supported, thus indicating many horizons of tree-growths that have not resulted in the formation of coals.

Then all through the series the strata are more or less marked by vegetable remains, often very fragmentary and all apparently drifted. These remains chiefly belong to *Lepidodendron* and its detached leaves and fruit, and to the ferns *Sphenopteris affinis* and *Cyclopteris flabellata*. We have also seen that several of the marine beds contain pieces of *Lepidodendron* and other wood, often incrusted with *Spirorbis*, along with their more characteristic fossils.

So that from the coals themselves, from the beds with *Stigmariæ*, from the plant-bearing strata generally, and from the drift wood in the marine limestones there is evidence enough of the abundance of vegetation in and about the Fifeshire area during this early Carboniferous period, and of both the vegetation and the geographical conditions being such as were suitable for the production of coal-growths, though, for some reason, not for their development into thick workable seams.

Though *Stigmaria* is so common in these Lower Carboniferous rocks, I have not observed any remains of the evenly ribbed and scarred stems of the more typical forms of *Sigillaria.* The short, upright stems, and prostrate, flattened trunks of trees that occur above the coals, or in some of the sandstones and shales, are for the most part coarsely and irregularly ridged and furrowed. Very rarely they show the lozenge-shaped scars of *Lepidodendron.* But possibly the others are only another form, or state of preservation, of the same tree; for the numerous remains of branches, small twigs, and leaves of *Lepidodendron* found in these rocks indicate that the prevailing tree or trees of the period must have belonged to that family.

Stigmarian roots or rootlets are repeatedly found in strata containing marine fossils, or with groups of species such as the remains of Ganoid fishes, Entomostraca, *Spirorbis*, and other organic remains which could not have had terrestrial habits*. In such cases the *Stigmariæ* give the impression of being contemporaneous with the other fossils, and thus to have existed beneath the surface of water, though in some cases they may have passed down, by process of growth, from a stratum or land surface above, after the deposition of the bed in which they are found. The following are some of the instances of this which I have observed:—

At Randerstone, in Limestone No. 9, it occurs abundantly with the scales of small Ganoids, *Leperditia Okeni*, var. *extuberata*, and *Spirorbis* sp.

At Fife Ness it occurs in shale (as rootlets), with the scales of small Ganoids, coprolites, *Myalina*? sp., *Leperditia Okeni*, var., *Spirorbis* sp., and *Sphenopteris affinis.*

West of Pitmilly Burn it occurs in limestone, with the scales of *Megalichthys*? and other Ganoids, *Littorina scotoburdigalensis*, *Myalina modioliformis*, *Leperditia Okeni*, var., *Beyrichia subarcuata*, and *Lepidophyllum.*

North of Kingsbarns Harbour it occurs in limestone, with *Macrocheilus striatulus*, *Littorina scotoburdigalensis*, *Murchisonia quadricarinata*, *Myalina modioliformis*, *Bairdia siliquoides*, *B. præcisa*, *Kirkbya spiralis*, and *Leperditia Okeni*; and it has already been noticed as occurring in the lower part of the limestone east of Randerstone Castle, associated with *Orthoceras* and other marine fossils.

I may here mention another and kindred set of facts to be observed in these rocks. In several cases the marine beds immediately follow a seam of coal with fireclay full of *Stigmaria* beneath; or if

* *Stigmaria* occurs in much the same way in some of the parrot-coals of the Coal-measures. In a coal of this sort at Pirnie Colliery, Fifeshire, its roots and rootlets are found with the remains of *Megalichthys Hibberti*, *Strepsodus sauroides*, *Ctenacanthus* sp., and other large fishes, and species of *Anthracomya*, *Spirorbis*, and *Carbonia.*

they do not immediately follow, they are in close contiguity to them.

This holds true with zones 5, 10, and 12 of the Pittenweem and Anstruther section, and with the Limestones Nos. 3 A and 4 of the Randerstone series; also with the limestone north of Kingsbarns Harbour, already mentioned, as well as with a five-feet *Myalina*-bed near the Rock and Spindle. In some of these instances the marine fossils (Crinoids, *Producti*, &c., in the case of zone 5) are found close down to the coal; in others there is a thin bed of dark shale, containing Ganoid scales and plants, between the coal and the marine stratum.

All these facts apparently suggest that the marine conditions on the one hand, and the conditions favourable to tree- or coal-growths on the other, were not widely separated in this area, and that the former followed the latter repeatedly as a matter of easy sequence.

In the determination of the species noticed in this paper I must acknowledge the great assistance afforded me by my friend Mr. John Young, of the Hunterian Museum, Glasgow; and to Dr. Traquair I am in some cases indebted for the identification of the fish-remains.

Notes on the Species.

Orthoceras cylindraceum, Flem., Annals Philosophy, vol. v. pl. 31. f. 3.

The *Orthoceras* which occurs in several of the Randerstone beds comes near to this species. It is eight or nine inches long, tapers slowly, has numerous septa and a central siphuncle. It is never very plentiful, except at the base of the limestone east of Randerstone Castle, and there scores of specimens (casts) may be seen within a few square yards.

Nautilus planotergatus?, M'Coy, Syn. Carb. Foss. Ireland, p. 18, pl. ii. f. 2.

Specimens of more than one species of *Nautilus* are found at Randerstone. They are all more or less crushed and not easy to identify. Most of my examples belong to a form about four inches in diameter, with compressed, quadrangular whorls, and which appears to come near to the *N. planotergatus* of M'Coy.

Other specimens belong to a smaller form with convex whorls.

Some examples of the former are coated with an incrusting coral and *Spirorbis*, and the shell is excavated by a boring-sponge or annelid (?).

Bellerophon costatus, Sow.

A large *Bellerophon* is found in limestone No. 7 at Randerstone. It is thick-shelled, an inch and a half wide at the aperture, has a strong, elevated keel, and rather coarse, somewhat irregular striæ of growth. Altogether it strongly resembles *B. costatus* as figured by De Koninck*.

* Descr. Anim. Foss. pl. xxvii. f. 2.

LITTORINA SCOTOBURDIGALENSIS, Etheridge, Quart. Journ. Geol. Soc. vol. xxxiv. p. 18, pl. ii. f. 26, 27.

This little univalve is exceedingly abundant in some of the beds about Billow Ness and Pittenweem. What I take to be typical examples have rounded whorls, which, in good preservation, show dark, transverse bands of colour.

LITTORINA? BILINEATA, sp. nov.

I have several examples of another little univalve, found along with the preceding species in the limestone of Zone 7, Pittenweem, which appears to be distinct and undescribed.

It is about $\frac{1}{6}$ of an inch high, with a depressed spire less than half the height of the body-whorl. The body-whorl is flat-topped, channelled at the suture, compressed at the sides, which slope outwards, and subangulate where the sides bend over towards the suture; two spiral impressed lines traverse the upper half of the whorl, the lowermost near the centre of the whorl and the other midway between it and the angulation. The aperture is subovate, round below, with the outer lip angulate above. Some specimens show a slight umbilicus, and most of them appear to be rather thick-shelled.

The generic affinities of this shell (as well as of the preceding species) are not very clear, and it is placed in *Littorina* with some doubt.

LACUNA ANTIQUA?, M'Coy, Syn. Carb. Foss. Ireland, p. 32, pl. v. f. 24.

One of the most common univalves of the limestone east of Randerstone Castle is a small shell that may possibly belong to *Euomphalus*, though it agrees so closely with M'Coy's figures and descriptions of his *Lacuna antiqua*, except in the form of its aperture, that I doubtfully refer it to that species. The shell is depressed and formed of three whorls; the body-whorl is large, rounded, and $\frac{1}{10}$ of an inch wide; the spire is small, the umbilicus large, and the aperture is round and entire.

MACROCHEILUS? STRIATULUS, n. sp.

This is a comparatively common shell in some of the Randerstone beds, and it is found more sparingly in Zones 10 and 18 of the Pittenweem and Anstruther section.

The largest specimens are $\frac{3}{10}$ of an inch long, and $\frac{1}{10}$ or rather more wide. The body-whorl is three fourths of the entire length, wide and flat above, and contracted towards the base. The spire is short and formed of four or five flattish whorls. The surface is spirally threaded with fine and regular lines in well-preserved specimens.

Professor De Koninck, who has kindly examined specimens of this shell, remarks that it has some resemblance to *Macrocheilus canaliculatus*, M'Coy, and that it is doubtful whether it belongs to *Macrocheilus*, an opinion with which I entirely agree.

TROCHUS SERRILIMBA, Phillips, Geol. Yorks. pl. xv. f. 30.

A small elongately trochiform shell occurs with the other univalves in the limestone east of Randerstone Castle. It is one fifth of an inch in length, and one eighth wide, with from six to seven gradually increasing and strongly tuberculated whorls; and it seems to be identical with *Trochus serrilimba*, Phillips, so far as can be judged from the figure of that species in the 'Geology of Yorkshire.'

AVICULA RECTA, M'Coy, Syn. Carb. Foss. Ireland, p. 84, pl. xiii. f. 24.

Specimens of an Aviculoid shell having much the character of this species occur in various beds. They are rather longer compared with the width than M'Coy's figures, but they have the surface ornamented with the same regular raised lines of growth as his species.

CYPRICARDIA BICOSTA, sp. nov.

This shell has only occurred in the limestone to the east of Randerstone Castle, where it is pretty common.

It is small, thick-shelled, subquadrate in outline, and has two ribs or keels running from the umbo diagonally to the posterior portion of the valve. It is $\frac{1}{4}$ of an inch long and $\frac{1}{5}$ of an inch wide.

MYALINA MODIOLIFORMIS, Brown.

Avicula modioliformis, Brown, Fossil Conchology, pl. lxvi. f. 19.
Myalina communis, Kirkby, MS.

I am not sure that the *Myalina* of the shell-beds of the east of Fife is the same as the Water-of-Leith shell found at Woodhall, and described by Capt. Brown as *Avicula modioliformis*; but I think it possible that it is so, and adopt this specific name rather than risk the creation of a synonym.

The Fifeshire shell, however, appears to be distinct from *M. crassa*, with which Mr. Etheridge has identified the Woodhall species, for the following reasons:—its relatively larger and more gibbous umbones; its more delicately striated cartilage-area; its regular, wide-apart, imbricating lines of growth; and its possession of an anterior tooth and socket in each value.

It is also a smaller shell, rarely exceeding an inch and half in diagonal length. It is always found best developed in the limestone and calcareous ironstones; and it is only in such specimens that the peculiarities of its hingement are to be seen. In the shales it is often very thin-shelled, with little or no cartilage-area, and might easily be mistaken for a species of *Anthracomya* were it not for its characteristic lines of growth.

At one or two localities a larger *Myalina* is found, and it appears to come nearer *M. crassa*. The best examples of this form that I have seen occur at the "Pans" west of Crail, in a limestone that represents another outcrop of Zone 10 of the Pittenweem and Anstruther section. It is nearly three inches in length, and has the more terminal umbones and strong cartilage-striæ of *M. crassa*, though scarcely so thick-shelled as specimens of that species found in the Carboniferous-Limestone series.

SANGUINOLITES ABDENSIS, Etheridge, Geol. Mag. 1877, vol. iv. p. 246, pl. xii. f. 9–11.

This species is very abundant in Zones 3 and 10 of the Pittenweem and Anstruther section; it is also found in some of the Randerstone beds and in a limestone near Craig Hartle. It varies somewhat in length, some examples having the posterior side more drawn out, with the diagonal ridge more pronounced and slightly arcuate.

SANGUINOLITES SUBPLICATUS, sp. nov.

This species only occurs in Limestone No. 5 at Randerstone, where the examples are usually more or less flattened by pressure. It is very probably the shell termed *Modiola* in the east of Fife sheet No. 41 of the Geological Survey Maps; but it has more the character of *Sanguinolites* than of the latter genus, and it does not seem far removed from *S. plicatus* as figured by Portlock *. It may be described provisionally as follows:—

About two inches long and $\frac{7}{10}$ wide; thin-shelled; with nearly straight and parallel dorsal and ventral margins, the latter with a slight sinus below and rather behind the umbo. The anterior side is short and rather pointed; the posterior is long and obliquely truncate. The umbo is wide, and from it to the postero-ventral angle runs a well-marked diagonal ridge. The surface is marked by strong lines of growth, which occasionally almost take the form of plications.

SEDGWICKIA GIGANTEA, M'Coy, Syn. Carb. Foss. Ireland, p. 62, pl. xi. f. 40.

I have several specimens of a large *Schizodus*-shaped shell from Limestone No. 6, Randerstone, which evidently come very close to the *Sedgwickia gigantea*, M'Coy. The specimens, which are all more or less crushed, are thin-shelled, from 3 to $3\frac{1}{4}$ inches long, 2 inches wide, and have the anterior side marked with the regular, strong ridges, parallel with the margin, that are characteristic of the genus, the remainder of the surface being comparatively smooth.

PLEUROPHORUS ELEGANS, sp. nov.

This shell is extremely abundant in Limestone No. 10 at Randerstone, associated with *Littorina scotoburdigalensis*. Prof. de Koninck thinks it comes near *Cypricardia cylindrica*, M'Coy, though he agrees in referring it to *Pleurophorus* as a new species. It may be described as follows:—

Elongate, less than half as wide as long, convex, and thick-shelled. Both dorsal and ventral margins slightly convex. The anterior side very short, narrow, and somewhat pointed; the posterior side narrow towards the extremity and obliquely truncate. The umbos

* Geol. Londonderry, pl. xxxiv. f. 18.

are wide and incurved; a faint diagonal ridge runs from each towards the postero-ventral angle, and behind them extends a narrow inflected cartilage-area, while in front is a comparatively wide lunette. The surface is marked by numerous strong lines of growth. The muscular impressions and pallial line are well shown in casts, and a strong umbonal rib bounds the anterior adductor behind. Length three quarters of an inch.

List and Vertical Range of Species found in the Calciferous Sandstone of the East of Fife.

	Range below the Carboniferous Limestone.			
	To 500 ft.	From 500 to 2300 ft.	From 2300 to 3000 ft.	From 3000 to 3800 ft.
Calamites, sp.	*	*	*	*
Carpolithes sulcatus, *Lindley*	......	......	*	*
Cyclopteris flabellata, *Brongn.*	......	......	*	*
Dadoxylon	......	*	......	*
Lepidodendron, sp., with Lepidophyllum and Lepidostrobus	*	*	*	*
Sphenopteris affinis, *Lindley*	*	*	*	*
—— dilatata, *Lindl.*	......	......	*	
Stigmaria	*	*	*	*
Fucoid ?	......	*		
Alveolites septosus, *Flem.*	......	......	*	
Lithodendron junceum, *Flem.*	*			
Stenopora tumida, *Phill.*	......	*	*	*
Zaphrentis, sp.	*			
Archæocidaris Urii, *Flem.*	......	*		
—— sp.	......	......	......	*
Actinocrinus, sp.	......	*		
Platycrinus, sp.	......	*		
Poteriocrinus, sp.	......	*		
Serpulites carbonarius, *M'Coy*	*			
Spirorbis globosus, *M'Coy*	......	......	......	*
—— helicteres, *Salter*	......	*	......	*
—— carbonarius, *Murch.*	*	*	*	*
Bairdia plebeia, *Reuss*	*	*	......	*
—— brevis, *Jones & Kirkby*	......	*		
—— Hisingeri, *Münster*	......	*	......	*
—— subelongata, *J. & K.*	......	*		
—— subcylindrica, *Münst.*	......	......	......	*
—— præcisa, *J. & K.*	......	......	......	*
—— nitida, *J. & K.*	......	......	......	*
—— siliquoides, *J. & K.*	......	......	......	*
Beyrichia subarcuata, *Jones*	......	*	*	*
—— subarcuata, var.	......	......	......	*
—— radiata, *J. & K.*	......	*		
—— crinita, *J. & K.*	......	......	*	
Carbonia fabulina, *J. & K.*	......	*	*	*
—— Rankiniana, *J. & K.*	......	*	*	*
—— subula, *J. & K.*	......	......	*	*
—— ? bairdioides, *J. & K.*	......	......	......	*

List and Vertical Range of Species (continued).

	Range below the Carboniferous Limestone.			
	To 500 ft.	From 500 to 2300 ft.	From 2300 to 3000 ft.	From 3000 to 3800 ft.
Cythere Jonesiana, *Kirkby*	......	......	......	*
—— æqualis, *J. & K.*	......	......	......	*
—— intermedia, *Münst.*	......	......	......	*
—— superba, *J. & K.*	......	......	*	*
—— cypridiformis, *J. & K.*	......	......	......	*
Kirkbya permiana, *Jones*	*			
—— spiralis, *J. & K.*	......	......	*	*
—— plicata, *J. & K.*	......	......	......	*
Leperditia Okeni, *Münst.*	*	*	*	*
—— ——, var. scotoburdigalensis, *Hibbert*	......	*	*	*
—— ——, var. elongata, *J. & K.*	......	......	......	*
—— ——, var. attenuata, *J. & K.*	......	......	......	*
—— ——, var. extuberata, *J. & K.*	......	......	......	*
—— ——, var. obtusa, *J. & K.*	......	......	*	
Dithyrocaris, sp. (tooth)	......	......	......	*
Leaia Leidyi *Jones*	......	......	*	*
Archæopora nexilis, *De Kon.*	......	......	*	
Ceriopora similis, *Phill.*	......	......	......	*
Distopora megastoma, *M'Coy*	......	......	......	*
Fenestella tuberculocarinata, *Eth.*	......	*	*	
—— plebeia, *M'Coy*	*	*	*	
—— Morrisii, *M'Coy*	......	......	*	
Synocladia, sp.	......	......	*	
Athyris ambigua, *Sow.*	*	*		
Chonetes polita, *M'Coy*	*			
Discina nitida, *Phill.*	......	*		
Lingula mytiloides, *Sow.*	*	*	......	*
—— squamiformis, *Phill.*	*	......	......	*
Orthis resupinata, *Martin*	*			
Productus semireticulatus, var. concinnus	*			
—— ——, var. Martini	......	*		
—— cora, *D'Orbigny*	*			
—— longispinus, *Sow.*	*			
—— punctatus, *Mart.*	*			
—— aculeatus, *Mart.*	*			
—— Youngianus, *Dav.*	*			
Rhynchonella pleurodon, *Phill.*	*	*	......	*
Spirifera trigonalis, *Mart.*	*			
—— ovalis, *Phill.*	*			
Spiriferina cristata, *Schlotheim*	......	*		
Streptorhynchus crenistria, *Phill.*	......	*		
Terebratula hastata, *Sow.*	*			
Avicula recta?, *M'Coy*	*	......	......	*
—— sp.	*			
Aviculopecten interstitialis, *Phill.*	*			
—— fimbriatus, *Phill.*	*	*		
—— ornatus, *Eth.*	*			
—— depilis?, *M'Coy*	*			

List and Vertical Range of Species (continued).

	Range below the Carboniferous Limestone.			
	To 500 ft.	From 500 to 2300 ft.	From 2300 to 3000 ft.	From 3000 to 3800 ft.
Aviculopecten granosus, *Phill.*	......	*	......	*
—— arenosus, *Phill.*	......	*		
—— sp.	......	......	*	
Anthracosia, sp.	......	......	......	*
Anthracomya scotica, *Eth.*	......	*		
Arca Lacordairiana, *De Kon.*	*			
Cypricardia oblonga, *M'Coy*	*			
—— glabrata, *Phill.*	......	......	*	
—— bicosta, sp. nov.	......	......	......	*
Edmondia rudis, *M'Coy*	*	*	*	
Leda attenuata, *Flem.*	*	*	......	*
—— sp.	......	......	......	*
Leptodomus costellatus, *M'Coy*	......	*	*	
Lithodomus dactyloides, *M'Coy*	......	......	......	*
Modiola divisa, *M'Coy*	......	......	......	*
Myalina modioliformis, *Brown*	......	......	*	*
—— crassa, *Flem.*	......	......	......	*
—— sublamellosa, *Eth.*	*	......	......	*
Nucula gibbosa, *Flem.*	......	*		
—— lineata, *Phill.*	......	......	......	*
Pleurophorus elegans, sp. nov.	......	......	......	*
Pteronites persulcatus, *M'Coy*	*			
Sanguinolites tricostatus, *Portlock*	*			
—— plicatus, *Port.*	*			
—— abdensis, *Eth.*	*	......	.....	*
—— subplicatus, sp. nov.	......	......	......	*
Schizodus Salteri, *Eth*	......	......	*	*
—— axiniformis, *Phill.*	*	*	......	*
—— carbonarius, *Portl.*	......	*		
—— unioniformis, *Phill.*	......	*		
Sedgwickia gigantea, *M'Coy*	......	......	......	*
Venus, sp.	......	*		
Dentalium priscum, *Goldfuss*	*	*		
—— scoticum, *J. Young, MS.*	......	*		
Euomphalus carbonarius, *Sow.*	*			
—— catillus, *Mart.*	*			
—— neglectus, *M'Coy*	......	*		
—— acutus, *Sow.*	......	*		
Lacuna antiqua ?, *M'Coy*	......	......	......	*
Littorina scotoburdigalensis, *Eth.*	......	......	*	*
—— bilineata, sp. nov.	......	......	*	
Loxonema rugifera, *Phill.*	*			
—— scalaroidea, *Phill.*	......	*	......	*
Macrocheilus imbricatus, *Sow.*	*	......	......	*
—— acutus, *Sow.*	*	*	*	*
—— fusiformis, *Sow.*	......	*	......	*
—— ? striatulus, sp. nov.	......	......	*	*
Murchisonia elongata, *Portl.*	......	......	*	
—— quadricarinata, *M'Coy*	*	......	......	*
—— striatula, *De Kon.*	*	*	*	*

List and Vertical Range of Species (continued).

	Range below the Carboniferous Limestone.			
	To 500 ft.	From 500 to 2300 ft.	From 2300 to 3000 ft.	From 3000 to 3800 ft.
Murchisonia angulata, *Phill.*	......	......	......	*
—— sp. nov.?	......	*		
Naticopsis plicistria, *Phill.*	*	......	......	*
—— elliptica, *Phill.*......	......	......	......	*
—— sp......................................	......	......	......	*
Pleurotomaria Yvanii, *Lév*	*	*		
Trochus serrilimba, *Phill.*	......	......	......	*
Bellerophon costatus, *Sow*................	......	......	......	*
—— Urii, *Flem.*	......	*	*	
—— decussatus, *Flem.*	*	*	*	*
Nautilus quadratus, *Flem.*	*	*		
—— planotergatus, *M'Coy*...............	......	......	......	*
—— sp......................................	......	......	......	*
Orthoceras attenuatum, *Flem.*	......	*		
—— cylindraceum, *Flem.*	......	......	......	*
Ctenacanthus, sp..........................	......	*	......	*
Ctenodus, sp................................	......	*		
Ctenoptychius, sp.	......	......	......	*
Diplodus, sp................................	......	......	*	*
Eurynotus crenatus, *Ag.*	......	......	*	*
Megalichthys Hibberti?, *Ag.*	......	......	......	*
Nematoptychus Greenockii, *Ag.*	......	......	......	*
Pœcilodus obliquus, *Ag.*	......	......	......	*
Rhadinichthys brevis?, *Traquair*	......	*		
Rhizodus Hibberti, *Ag.*	......	*	*	*

42. *On the* Predevonian Rocks *of* Bohemia. By J. E. Marr, Esq., B.A., F.G.S.* (Read June 9, 1880.)

Contents.

§ 1. Introduction.

On examining the geological map of the neighbourhood of Prague, by Profs. Krejči and Helmhacker, it will be seen that the Predevonian rocks are in many places covered by others of Cretaceous agé. The country in which they are developed is in fact a plateau formed by a Postcretaceous plain of marine denudation, in which the rivers have consequently not had much time to erode valleys; the sections of the Predevonian rocks are therefore principally found along the sides of narrow valleys, which mostly run at right angles to the strike of the beds. This strike, as may be seen in the above-mentioned map, or that of M. Barrande, is in a prevailing E.N.E. and W.S.W. direction, and a system of faults runs parallel with it and was produced at the same time. By consulting Prof. Krejči's 'Geology of Bohemia' (printed in the Czech tongue), the sharpness of some of the folds may be seen (*cf.* figs. 173, 180, &c.); in fact, although the basin itself has a very simple structure, it contains some very complicated foldings and repetitions in places. These may be well seen in the neighbourhood of Beroun, and are shown on Krejči's map. These foldings, with the parallel faults, were produced in Precarboniferous times, for Carboniferous rocks rest, nearly horizontally, on the folded and faulted Cambrian, at Stradonice, near Beroun.

Another series of faults, however, affects the Predevonian rocks and also the Carboniferous, and is hence Postcarboniferous, and this series is approximately at right angles to the former. The folds affect hard limestones and grits and soft shales alike; and as the rocks have been released from strain by crumpling and faulting, the phenomenon of cleavage is of somewhat rare occurrence. The Precambrian rocks are slightly cleaved, but I have seen no true cleavage in any of the Cambrian or Silurian rocks. This is a fortunate cir-

* The author was sent out during the past year, by the University of Cambridge, with a grant from the Wort's fund (Grace 2, Feb. 6th, 1879), to examine and report upon the Cambrian and Silurian rocks of Bohemia, with special reference to the boundary between them. In the following paper the results obtained are laid before the Society. Professor Sedgwick's nomenclature is adopted in this paper, and hence the term Silurian is limited to the beds containing Barrande's faunas E, F, G, and H.

cumstance, as tending to the better preservation of the exceptionally rich fauna of the Bohemian basin.

I would here thank those geologists from whom I have received very valuable assistance ; and, first, let me state the immense benefits I have received from M. Barrande, by his works, by his many personal kindnesses to me, and, lastly, by the wonderful example of perseverance, which is the astonishment of any one who has even cursorily examined a slight portion of his stupendous work, in the field. I have also to thank Dr. Novák, of Prague, and Herr Dusl, of Beroun, for much aid in the field and museum. My acknowledgments are also due to Profs. Hughes and Bonney for much kind assistance.

§ 2. Description of the Strata.

I. *Precambrian Rocks.*

On examining a geological map of Bohemia, it will be observed that the well-known basin of M. Barrande lies with its axis in an approximately E.N.E. and W.S.W. direction, and is bounded on nearly all sides by a series of granites, gneisses, &c., referred to by Murchison ('Siluria,' p. 372) as of Laurentian age. He remarks that on them rest vast "masses of conglomerates, grits, and crystalline schists, B, A;" he further states that the latter are of Cambrian age. It would have been impossible, in the short time I had at my disposal for the examination of these gneissose rocks, to have detected any order in them; I therefore confine myself to a few notes on their lithological character and general strike.

The gneissose series is well exposed in the neighbourhood of Budweis. Proceeding in a south-westerly direction, from Budweis to the village of Chlumiček, soon after leaving the Brown-Coal formation a section is seen in gneiss, by the roadside south of Kališt; it dipped north at a high angle, and was well foliated in places. Nearer Chlumiček the gneissose rock becomes interspersed with small garnets, which seemed to have been produced owing to the contiguity of a mass of intrusive eclogite. East of the village of Holobau, on the road between Chlumiček and Krumau, a white foliated quartzose rock, with many amber-coloured garnets, is seen, striking nearly E. and W., and containing a dyke of black eclogite. At the eastern extremity of Krumau a crystalline limestone is seen by the roadside; it is strongly foliated and contains silvery mica; it dips in a northerly direction, and underneath it occurs a gneiss having the same dip. Between the two there is a band of graphite, but whether as a vein or as a bed I could not ascertain.

Lying between the gneissose series and a mass of conglomerates &c., which form étage B of M. Barrande, and unconformable to the latter, which I hope to show are of the age of the Harlech group of Britain, occur the beds forming étage A, Barrande. I was unable to find any section showing the relations between this group and the gneissose series; but that it belongs to a separate formation seems clear from the following facts:—first, the two are totally different in lithological characters; secondly, whereas the earlier group is highly metamorphosed, the later one has been subjected to but slight metamorphism, and that only in places; thirdly, the strike is entirely different in the two groups, the beds of étage A having a N.E. and S.W. strike; finally, this group contains fragments of the preceding.

The relations of étage A to the group above may be seen in many sections, but notably in the neighbourhood of Přibram, as shown in the following diagrammatic section from Jinec (Ginetz) to Milin (fig. 1, p. 594).

The beds of étage A have a strong lithological similarity wherever exposed; they consist of a series of green schists, grits, ashes, and breccias, interstratified with variously coloured hornstones. Massive beds of the latter occur in this series, in the neighbourhood of Prague, at Šarka, and on the other side of the Moldau, near Bohnice, also in the neighbourhood of Beroun, at Hudlice.

Green ashy beds of this age with imperfect cleavage are seen at Troya, Hudlice, Broum, Hluboš, &c.; but, so far as I have seen, they are unaccompanied by any contemporaneous flows.

II. *Cambrian Rocks* (Sedgw.).

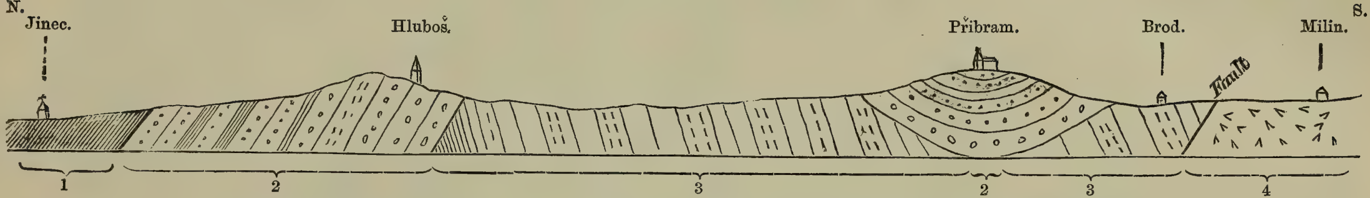
Étage B, Barr. This is excellently exposed along the banks of the Littava, between Jinec and Přibram, as shown in fig. 1. Near the village of Čenkau, the shales of étage C are underlain by coarse grits composed of granitoid materials; beneath these are finer green grits succeeded in descending order by a series of interstratified compact red shales, yellow grits, and finely laminated green shales: these seem to be repeated by foldings. On reaching a mill by the river-bank, south of Hluboš, the base of this series is seen resting, as before mentioned, with a very marked unconformity, on the last-described series (fig. 1). The lowest beds of the upper series consist of coarse conglomerates, the pebbles of which increase in size on approaching the base, where many of them exceed two feet in diameter. The larger ones consist chiefly of hornstones, identical in character with those of étage A; of other pebbles there are abundance of quartz, of a blackish schist, &c. The strike of this group differs somewhat from that of the group below, and agrees with that of the whole of the succeeding étages, viz. E.N.E. and W.S.W.

As an excellent description of the lithological characters of the fossiliferous groups composing the basin is given by M. Barrande (*cf.* Déf. des Col. iv. p. 96 *et seqq.*), I shall merely give a short outline of their nature.

Étage C contains the well-known primordial fauna, and is exposed on the northern side of the basin in the neighbourhood of Skrey, and on the southern at and near Jinec (Ginetz). It does not extend all round the basin, but is overlapped by the upper beds. At Skrey it consists of very fine greyish or blackish shales; at Jinec of somewhat coarser and slightly gritty shales of an olive-green colour, and often weathering into large concentric spheroids.

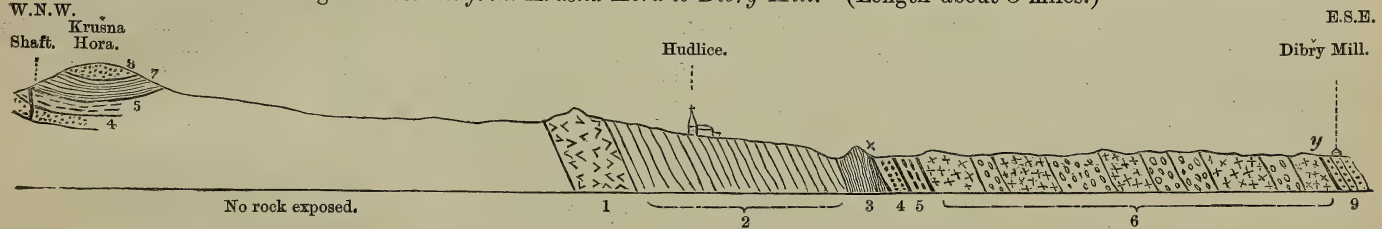
Etage D is subdivided by M. Barrande into five "bandes,"

Fig. 1.—*Section from Jinec (Ginetz) to Milin.* (About 12 miles.)



1. Shales of étage C.
2. Shales, sandstones, and conglomerates, étage B.
3. Schistose and ashy beds, hornstones, &c., étage A.
4. Granite.

Fig. 2.—*Section from Krušna Hora to Dibřy Mill.* (Length about 3 miles.)



1. Massive hornstone.
2. Green ashy beds.
3. Black slates.

} Étage B.

× Unconfomity.
y. Fault.

4. D d 1 *α*.
5. D d 1 *β*.
6. Contemporaneous porphyrites and agglomerates.
7. D d 1 *γ*.
8. D d 2.
9. D d 4.

} Étage D.

1–5; the whole is characterized by him as the "étages de quartzites;" the lowest of the five bands is further subdivided into α, β, and γ.

D d 1 α rests with a slight unconformity on C, or on still lower formations. It consists of a conglomerate, with green, sandy matrix and small quartz pebbles, where it rests upon C, on the right bank of the Beroun, between Teyřov and Skrey. It is also exposed to the east of Hudlice, where it rests on B, and consists of interstratified green grits and conglomerates. At Krušna Hora, where it has proved fossiliferous, it consists of quartzose grits with green grains (fig. 2).

D d 1 β rests conformably upon α at Krušna Hora &c. (see fig. 2). It consists of black, green, and red pisolitic ironstones, containing, I was informed, a considerable quantity of phosphorus. The pisolitic grains are frequently the colour of the matrix in which they are imbedded; but very often they consist of alternating shells of light and dark green, imbedded in a blackish or reddish matrix.

D d 1 γ is of a much greater thickness than α and β together. It consists of exceedingly fine, slightly micaceous, black muddy shales, with a somewhat flaky appearance, not usually very fossiliferous. At Vosek, to the S.W. of the basin, where fossils are abundant, they are found imbedded in ironstone nodules an inch or two in diameter, which are by no means generally distributed throughout this horizon.

D d 2, the most arenaceous band of the "étages de quartzites," consists chiefly of white or light pink thickly bedded grits, with occasional thin beds of sandy shale, and in some places, in the neighbourhood of Beroun, there is a fairly thick series of pinkish flaggy grits, ripple-marked, and with fucoid markings and annelid-tracks.

D d 3 consists of fine black muddy shales, with very minute mica flakes; with these are interstratified occasional thin beds of grit. The whole is of no great thickness.

D d 4. Gritty, ferruginous, and very micaceous shales, of a predominating greyish colour, false-bedded, ripple-marked, and with many fucoid marks and annelid-tracks. The series contains a band of oolitic ironstones running parallel to the road between Prague and Beroun, as shown in the map by Krejči and Helmhacker. In the neighbourhood of Vraž, to the N.E. of Beroun, some calcareous beds occur, forming a strong feature.

The limestone is nodular and of a dark colour, with interstratified shales, and very fossiliferous.

D d 5. A series of unctuous olive-green shales, interstratified, especially towards the top, with gritty shales and grits. Prof. Krejči divides this band into two (*cf.* his 'Geology of Bohemia,' p. 385): a lower shale division he terms "Břidlice Kralodvorské," from Kralův Dvůr, near Beroun; and an upper grit division, "Křemence Kosovské," from Mt. Kosov, also near Beroun. In the neighbourhood of Chodaun grey shales occur; near Prague, fine, black, very fossiliferous shales are interstratified with the olive-green shales. In addition, this band and the last (D d 4) are described as containing the "Colonies."

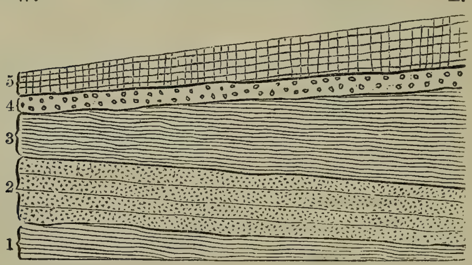
III. *Silurian Rocks.*

The Silurian epoch includes M. Barrande's étages E–H. Unlike the Cambrians, the prevailing rocks of this series are limestones, although shales occur here and there, and preponderate at the base of the series. From the manner in which the limestones vary in thickness, and thin out altogether in horizontal areas of no great extent, and from the way in which they differ from one another in lithological character, we should expect them to possess peculiar faunas; and this is found to be the case.

Étage E is divided into two bands by M. Barrande, the upper one calcareous, the lower one chiefly argillaceous.

E e 1 is found with invariable characters at all parts of the basin where exposed. It is composed chiefly of shales, but becomes calcareous towards the top, passing into E e 2. It rests, as stated by M. Barrande (Déf. des Col. iv. p. 109), unconformably upon the beds of D; such unconformity is well seen on the N. side of the Slivenec valley, about 300 yards W.N.W. of Gross Kuchel (see fig. 3). Here the lowest bed of E e 1 consists of a calcareous conglomerate with greenish pebbles, about four inches in thickness, resting on the denuded edges of greenish shales, underlain by thick yellow grits.

Fig. 3.—*Section on the N. side of Slivenec Valley.*
(Length about 15 yards.)



1. Olive-green shales.
2. Grits.
3. Olive-green shales, 2 feet thick at W. end, 5 feet thick at E. end.

} D d 5.

4. Conglomeratic bed 6–9 inches.
5. "Wafer" grapto-litic shales.

} E e 1.

Unfortunately, in most localities, the junction between D and E is concealed, or, where exposed, is a faulted one; in the neighbourhood of Beroun, however, it seems to be well exposed in two valleys, viz. near Kralův Dvůr and near Chodaun.

In each locality the grits of D d 5 are succeeded by similar grits with unstratified black bands, which I would refer to the base of E, and considered to have been derived by denudation from the uppermost grits of D d 5. Above these basement beds are everywhere found the beds of E e 1, capable of subdivision into three horizons, characterized by differences of lithological character and of their faunas, which are chiefly graptolitic. I shall treat of the faunas when comparing the beds with their English equivalents. The lowest of the three horizons consists of fine black mudstones, divided by bedding and joints into small squarish prisms, and sometimes into wafery shales. It contains also, in places, greenish gritty beds an inch or two thick, as at Litohlav. The middle horizon also consists of black mudstones, of a more flaggy character than the last, and containing calcareous nodules and bands, usually black also; these are the Anthracolite spheroids of M. Barrande (Déf. des Col. iv. p. 26).

The uppermost horizon consists of sandy and ferruginous shales, weathering brownish yellow, containing calcareous nodules, and passing into thin-bedded limestones, which compose the summit of E e 1. Between e 1 and e 2, in the valley of Tachlovice, is a band of oolitic ironstone.

E e 2. A greyish crystalline limestone, crowded with fossils, and of nearly unvarying character. At one locality, however, near Lodenice, it contains a yellowish ferruginous and calcareous shale. The fauna is exceedingly instructive, and shows how careful we should be not to conclude two deposits to be of different age, from their possessing different faunas at short distances apart. In the quarries around Prague and at Karlstein, Trilobites are exceedingly rare in this formation. At Lochkov, *Cromus* abounds, to the exclusion of other genera in any abundance. At Listice, *Sphærexochus* is very abundant, though rare elsewhere; other genera are rarer. Near St. Johann, *Calymene*, *Cheirurus*, *Staurocephalus*, *Lichas*, and *Acidaspis* are all abundant. In all these localities the rock containing these fossils presents the same lithological characters. At Lodenice, where the rock is somewhat different, *Arethusina* abounds, although rare elsewhere. It is but fair to state that the molluscan fauna does not vary to this extent.

Étage F. The two bands of this étage are of no great vertical thickness, and are not often seen in contact with one another. At present, a section is exposed in the quarries of Dvorec, near Prague, in which f 2 is seen superposed upon f 1. A light yellow siliceous band occurs between E and F in the Tachlovice valley, where f 1 appears to be absent.

F f 1 consists of blackish crystalline, thin-bedded limestones, with thin black shales. It is very black in the valley near Lochkov, not so much so at Dvorec and in the Slivenec valley; it does not seem to be of very wide extent.

F f 2. A very white crystalline limestone, except where stained pink by hæmatite. It is very well developed at Koněprus, and is not found all over the basin. Fossils are very locally distributed, even in the same sections. F f 2 contains some chert bands in places, as in the Tachlovice valley.

Étage G consists of two limestone bands, with an intermediate shale. The limestones are easily distinguished from any of those before described by their compact texture and strongly nodular character.

G g 1. A dark grey, compact nodular limestone, mottled with irregular black spots in places; the nodules are three or four inches in their longer diameters, which are parallel to the bedding. Interstratified black shale beds, a few inches thick, occur rarely. Chert nodules are irregularly distributed in the limestone. At Hlubočep a siliceous bed occurs at the top. Fossils are sparsely distributed.

G g 2. A compact, unctuous, mottled shale of no great thickness, with nodules and bands of grey limestone with black markings. The shale is usually of an olive-grey, leaden grey, green, or reddish colour.

G g 3 strongly resembles g 1 in lithological character, but is usually of a lighter colour, often stained pink, otherwise weathering to a buff-colour. The fauna, however, is very different, being characterized by the numerous genera of Cephalopoda which it contains.

Étage H consists of grits and shales: there is a total absence of any calcareous rock. It is divided into three bands of no great thickness.

H h 1. Grey non-micaceous shales, ripple-marked, and crowded with fucoid remains. It is well exposed at Hlubočep, Hostin, &c.

H h 2 resembles H h 1 in lithological character, but contains interstratified grit bands.

H h 3 is lithologically similar to H h 1.

§ 3. The Associated Igneous Rocks.

The igneous rocks of the Predevonian basin of Bohemia are many of them, at present, the subject of study of the eminent petrologist Bořicky. The following is a list of the principal ones which I noticed:—Granite, Quartz Felsite, Mica-trap, Porphyrite, Diabase, Diorite, Eclogite.

Granite.—This rock seems to be confined to the older Precambrian series. I have examined it in the neighbourhood of Mnichovice to the south of Prague. It is here very hornblendic. Near Klokočna, north of Mnichovice, a porphyritic granite is seen, with large white crystals of orthoclase.

To the south of Přibram, granite is seen in the neighbourhood of Milin, along the boundary between the older and newer Precambrian series. It, however, seems to be faulted against the newer series, as this is not much altered near the boundary with the granite. The granite is certainly Precambrian, for the basement conglomerates of the Cambrian system are largely made up of granitic materials.

Quartz Felsite occurs in dykes intruded in the Precambrian and Cambrian rocks in many localities. The dykes appear to be of normal character, and of no great interest.

Mica-trap. In the neighbourhood of Strašnice and Neu Strašnice, a few miles east of Prague, several mica-trap dykes cut through the shales of d 5. The dykes in every way resemble those occurring in the Lake district in rocks of about this age. Other localities for mica-traps are recorded by Professor Bonney (Q. J. G. S. vol. xxxv. p. 165). In a paper by Messrs. Gunn and Clough on the Silurian beds of Teesdale (Q. J. G. S. vol. xxxiv. p. 30) it is stated that "no mica-trap dykes are known in the Carboniferous beds of this district, or of any other part of the north of England, while such dykes are common in the Silurian districts of the Lake-country." The Bohemian mica-traps afford a remarkable additional case, which can hardly be a mere coincidence.

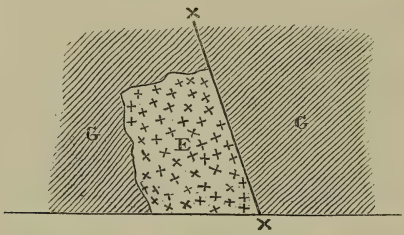
Porphyrite. There appears to have been an overflow of porphyrite lavas during the deposition of d 1 α & β. Above the conglomerate of d 1 α near Skrey occurs a great series of porphyrites and associated ashes and breccias, and a similar series is seen above the beds of d 1 β near Hudlice (fig. 2), also with ashes, breccias, and agglomeratic beds. These porphyrites are usually of a dull claret-red, with small plagioclase crystals, visible to the naked eye, and are very frequently amygdaloidal.

Diabase occurs intrusive in soft shales of Precambrian, Cambrian, and Silurian age, often running parallel to the bedding for some distance. It is excellently exhibited in the neighbourhood of Kuchelbad, especially opposite the inn of Vyskočilka, where it is intrusive in the shales of E e 1, which it frequently alters, both above and below. The diabase here exhibits beautiful spheroidal weathering; and similar weathering is seen in a mass of diabase intrusive in the shales of the colony at Hodkoviček. It often contains fragments of the rocks into which it intrudes: at Butovice, where it is intrusive in limestone bands near the summit of e 1, which are composed largely of *Otrhocerata*, the diabase itself contains many fragments of these Cephalopods, free from matrix, as discovered by M. Barrande.

Diorite occurs as dykes intruded usually into the older rocks of the basin. The dykes are generally fine-grained, have undergone considerable alteration, and are of little interest.

Eclogite (serpentine of Hauer's map). In describing the Precambrian rocks of the neighbourhood of Budweis, it was stated that there was a mass of eruptive eclogite in the neighbourhood of Chlumiček, which seemed to have converted the gneiss of the Precambrian series into a garnet rock. The gneiss seemed to me to become more granatiferous as it approached the eclogite, until at last all the black mineral (hornblende?) disappeared, and a white matrix containing amber-coloured garnets remained. On examining Hauer's map of Bohemia, it will be seen that the garnet rock which occurs to the west of Budweis does not run in the direction of strike of the Precambrian rocks, which is nearly E. and W., but surrounds masses of intrusive eclogite (serpentine of map). On the same map, also, it will be seen that other masses of garnet rock (as south of the Danube, near Krems, and some miles to the west of Gmünd, &c.) are invariably accompanied by masses of rocks mapped as serpentine. Hence the connexion does not seem to be accidental, and it appears probable that the metamorphic garnet rock is due to the intrusive eclogite. The eclogite itself, near Chlumiček, is of a dark olive-green colour. Near the small village of Krems, south of Chlumiček (not the Krems above mentioned), it is of a reddish hue; south of Slaviš, to the east of Chlumiček, it is of an amber-brown; whilst near Holobau it is black. In each locality it is very hard. The last-mentioned place yields a very interesting section (fig. 4), in which the eclogite is clearly seen to be intrusive. The section is to the north of the road, just before it crosses a stream to the east of the village of Holobau.

Fig. 4.—*Section by Bridge east of Holoban.* (Height about 10 feet.)



G. White quartzose foliated rock with amber-coloured garnets.
E. Hard black eclogite. ×× . Joint (and fault?).

Near Srnin, between this place and Krumau, occurs another mass of eclogite, probably connected with the former at no great distance below the surface, and altogether similar to it. It is of a brown colour*.

§ 4. Comparison of the Strata with English Deposits.

In Salter's Catalogue of Cambrian and Silurian fossils of the University of Cambridge some of the Bohemian beds are correlated with English deposits. A more detailed correlation is given by Dr. Hicks (Geol. Mag. dec. ii. vol. iii. table opposite p. 156; *cf.* also Hicks, Q. J. G. S. vol. xxxi. p. 552). Professor Krejči also, in his work on the Geology of Bohemia (pp. 461 *et seqq.*), gives a comparison of the Cambrian and Silurian rocks of the two countries. Sir R. I. Murchison (Siluria, p. 375), on the other hand, says, "For my own part, however, I have always thought that geologists should

* Professor Bonney has kindly examined a slide of this rock from Chlumiček, and given me the following note:—

"Your rock from Chlumiček has no claim whatever to be called a serpentine. The chief mineral is omphacite, with perhaps, as is commonly the case, some smaragdite. The other prevailing mineral is a decomposition product after garnet . . . . It has a peculiar fibrous structure and acts upon polarized light, the fibres radiating irregularly from a centre outwards. I have seen something like it in an alteration product of Cordierite . . . . That it is after garnet is shown not only by its mode of occurrence, but also by one or two bits of unaltered garnet remaining in the centre. There are a few brown microliths, in part probably only stains. The rock therefore is an eclogite, with most of the garnets replaced by a decomposition product. The great difference in the condition of the two principal minerals is rather curious, though not without parallel in the felspar and augite of some dolerites."—T. G. B.

not endeavour to synchronize any one British subdivision with an exact equivalent in distant foreign lands." In the case of Bohemia, however, we find so many similarities in both lithological and palæontological characters, *occurring consecutively through a series of beds*, that we cannot suppose them to be mere coincidences. These similarities are most striking in the beds which yield evidence of having been deposited in deep water.

I. Commencing with the Precambrian rocks, it is soon remarked that the two unconformable series in Bohemia strongly resemble those which have been named Dimetian and Pebidian by Dr. Hicks in Britain. On referring back to the description of the lithological characters of the lowest group in Bohemia, it will be seen to correspond exactly with that given by Dr. Hicks of the St. David's Dimetians. There is no indication of any intermediate group, such as that described in Britain as the Arvonian beds; but the green ash and hornstone series of Bohemia, constituting étage A, Barr., and, according to Professor Krejči, part of étage B also, is regarded by that geologist in his work on the country as contemporaneous with the Huronian rocks in America. It exactly resembles the Pebidian series of Britain, except in the greater development of the hornstones. As the Dimetian and Pebidian series of St. David's have been correlated by American and Scandinavian geologists with deposits in their own countries, it is not surprising to find similar formations occupying the same horizons in Bohemia.

II. The Precambrian rocks, as in Britain, are succeeded by a conglomerate series, not differing very much from the upper series of the former in their direction of strike, but nevertheless exhibiting a very marked unconformity. The resemblance between the Harlech beds of St. David's and the base of the Cambrian of Bohemia is surprising; not only do we meet with the basement conglomerate with large pebbles, easily detached from the matrix, but the yellow grits and the red shales are precisely similar to those beds at St. David's which have yielded fossils. It is too much to expect that these Bohemian beds will be found even tolerably fossiliferous, after the almost exhaustive researches of M. Barrande; but it is not impossible that organisms may yet be found, and the section by the roadside near the village of Cenkau seems well worth a lengthy search.

The beds of étage C, or the primordial zone of Barrande, have by many authors been compared to some part of the British series. Sir C. Lyell (Students' Elements, p. 487) correlates the Menevian beds and Lingula Flags with this étage. Dr. Hicks (Geol. Mag. dec. ii. vol. iii. table) places the Menevian beds only on this horizon. The Menevian fauna certainly bears a strong resemblance to the fauna of C, *e.g.* the occurrence in both of the genera *Paradoxides*, *Conocoryphe*, *Arionellus*, *Agnostus*, &c. I think, for reasons to be given presently, that étage C does not represent the whole of the Lingula Flags, if any portion of them. In lithological character its resemblance to the Menevian beds is very strong. They both seem to have been deposited in deep sea; one proof of this is given in Lyell's

'Students' Elements' (p. 485). Speaking of the Menevian beds, he says (from information by Hicks, Q. J. G. S. vol. xxviii. p. 174), "Blind Trilobites are also found, as well as those which have the largest eyes, such as *Microdiscus* on the one hand and *Anopolenus* on the other." In a lecture on deep-sea fishes delivered at Cambridge by Dr. Günther, he remarked that these fishes had either very large eyes or none at all, as ordinary eyes would be valueless at such a depth. Sir Wyville Thomson also, in his Voyage of the 'Challenger' (Atlantic, vol. i. p. 131), points out the resemblance of the eyes of the deep-sea *Cystosoma Neptuni* to those of *Æglina*. We may infer, therefore, that where we meet with a deposit containing Trilobites with abnormally large and abnormally small eyes, but not with those of ordinary size, they point to deep-sea conditions. This inference is justified by finding that beds containing such Trilobites have generally a fine-grained texture, and exhibit similar lithological characters over large areas.

The lowest bed of étage D, viz. d 1 α, has been described as conglomeratic in some places, gritty in others. At Krušna Hora, where it consists of grit, it has yielded abundance of *Lingula Feistmanteli*, the only fossil as yet known in it. I think this zone represents part of the Lingula Flags of Britain, and is, like them, of a shallow-water origin. Dr. Hicks, in above-cited table, correlates Lingula Flags with conglomerates.

D d 1 β is not very fossiliferous. Besides some *Lingulæ* and *Discinæ*, there are recorded from it *Harpides Grimmi*, *Amphion Lindaueri*, *Orthis desiderata*, and *Echinosphærites ferrigena*. The occurrence of *Harpides* with *Amphion* seems to indicate an admixture of primordial and later forms. This would agree very well with what we find in the Tremadoc Slates. But the lithological character of the beds is the most remarkable, for the pisolitic ironstones are absolutely undistinguishable from those of the Tremadoc Slates of our own area, and, like them, contain much phosphorus. Succeeded as these ironstones are by beds (d 1 γ) which have been recognized by many authors as of Arenig age, we can hardly help correlating them with the Tremadoc Slates.

D d 1 γ has the peculiar flaky and very fine black shales so characteristic of the more typical Arenig rocks of Britain. There are indications of this being a deep-sea deposit, from the eyes of its Trilobites. *Æglina* is abundant, and, on the other hand, several species of *Agnostus* occur. Even in the same genus, as pointed out by Herr Dusl, the eyes differ largely, *e. g.* in *Illænus*, of which *I. Katzeri* has aborted eyes, and *I. advena* very large ones. Being a deep-water deposit, we find that the fauna strongly resembles that of the British Arenig rocks, and still more strongly beds of that age in France, so that there certainly seems to have been a continuous sea at this period throughout Western Europe. The following genera occur in the Arenig rocks of Britain as well as in d 1 γ of Bohemia — *Æglina*, *Placoparia*, *Calymene*, *Trinucleus*, *Ribeiria*, *Redonia*, *Bellerophon*. The species of some of these genera strongly resemble one another in the two countries, as pointed out by Murchison (Siluria, p. 377), and *Bellerophon bilobatus* is common to the two. Graptolites also occur in this band in Bohemia, although not abundantly. *Graptolithus avus*, recorded by Krejči, seems to include fragments of more than one compound form; the same author also records a *Didymograptus* (*D. Suessi*). The Graptolites occur in deep-water deposits at several horizons (*e.g.* D d 3, d 5, E e 1), but are absent in beds formed in a shallower sea.

D d 2 was evidently deposited in shallow water, and cannot therefore be strictly compared with any British deposit. The fauna presents resemblances to that of the Lower Bala rocks of Britain.

D d 3 is another deep-water deposit, resembling many of the Bala shales of Britain. Many of the fossils of d 1 γ have returned with the recurrence of deep-sea conditions. Some obscure Graptolites at Vinice are apparently referable to *Climacograptus*. The most abundant Trilobite is *Trinucleus ornatus* (= *T. concentricus*).

D d 4 seems to have been for the most part deposited in shallow water. Its fauna is very similar to that of the Middle Bala. In it occurs abundance of *Calymene*, *Cheirurus*, *Phacops*, *Illænus*, *Trinucleus* (*T. ornatus* = *T. concentricus*, abundant here also), and various Cystideans. The limestone and calcareous shales described as occurring at Vraž point to deeper water, and present a resemblance to the Bala limestone. They contain *Cheirurus claviger*, *Phacops* (*Dalmannites*) *socialis*, var. *proœva*, *Illænus Salteri*, *Orthis elegantula* and other species, *Strophomena*, *Holopea*, &c.

D d 5 may partly represent Upper Bala beds. This and D d 4 being mostly shallow-water deposits, we cannot expect to find any strong resemblance to English formations; d 5 does, however, contain one zone of fine black shales, very similar to some of the English Bala shales, and apparently deposited in deep water. It rarely contains Graptolites.

III. The Silurian rocks, as before stated, rest with a slight unconformity upon the Cambrian series, and their basement beds are sometimes of a gritty and conglomeratic nature. These basement beds have as yet yielded no fossils, so that in Bohemia there is no sign of a shallow-water May-Hill fauna. The beds of E, especially of its lower division, are more strictly comparable with their British equivalents than any other beds of the basin; for they contain a series of graptolitic faunas which, as lately shown by Mr. Lapworth, in his most instructive paper on the Moffat series (Q. J. G. S. vol. xxxiv. p. 333 &c.), are exceedingly limited in a vertical direction, but widely spread horizontally.

The band e 1 contains three graptolitic faunas. The beds containing them have been already described, and their fossils will be considered at length, as the recognition of these three faunas is of the utmost importance in considering M. Barrande's theory of colonies. The lowest of the three was described as consisting of fine black prismatic mudstones with interstratified green bands, and these are exactly similar to the beds of the Birkhill Shales of Britain. The fauna presents a still more striking resemblance. I have found in them the following species:—

Monograptus cyphus, *Lapw.*
—— Becki, *Barr.*
—— tenuis, *Portl.*
—— proteus, *Barr.*
—— spinigerus, *Nich.*
—— triangulatus, *Harkn.*
—— turriculatus, *Barr.*
Rastrites peregrinus, *Barr.*
—— Linnæi, *Barr.*
Diplograptus folium, *His.*
—— tamariscus, *Nich.*
Climacograptus scalaris, *His.*
Retiolites, sp.

All the above species are characteristic of the Birkhill Shales. No other fossils than Graptolites have yet been found in strata proved to belong to this zone.

And not only does this zone resemble the Birkhill Shales, but it can, like them, be divided into a series of subzones characterized by various species of Graptolites. In the limited time at my disposal I was unable to define these subzones, especially as the whole of this zone is never exposed in one continuous section; but I made out that the lowest subzone consisted of what I may describe as "wafer shales"—black shales so thin as to be broken into any shape desired by the fingers, and crowded with Graptolites chiefly of two species, viz. *Rastrites peregrinus* and *Climacograptus scalaris*, which occur in thousands at this horizon, to the exclusion of any great abundance of other species. This subzone is well seen in the valley running up the side of Mount Kosov, near Kralův Dvůr (Beroun), also in the Chodaun valley, between Želkovice and Libomyšl, and in many other places. Another subzone is characterized by the abundance of *Monograptus turriculatus*; and this, as in Britain, occurs high up in the series. It is seen between Kuchelbad and Gross Kuchel, at Litohlav Mill, and near Zelkovice.

The next overlying fauna occurs in much more flaggy shales, with calcareous bands and concretions in places. Its graptolitic fauna is that of the Brathay Flags of the Lake district, and a similarity is observable in the lithological character of the two deposits. This is specially marked at Branik, where the beds are not so black as is usual in this zone in Bohemia. I have seen the following Graptolites in this zone (all of which occur at Vyskočilka, where the underlying zone is absent):—

Monograptus priodon, *Bronn.*
—— vomerinus, *Nich.*
Cyrtograptus Murchisoni, *Carr.*
Retiolites Geinitzianus, *Barr.*

All of these, except the *Cyrtograptus*, are abundant in many localities. The negative evidence is as strong as the positive, for although the two described faunas are not separated by any beds such as the Tarannon Shales (Pale Shales) of Britain, they do not, so far as I have seen, possess a single species in common.

A band of limestone always occurs between this zone and the overlying one. It contains abundance of *Cardiola interrupta*, *Orthoceras*, &c., and is probably about the horizon of the Middle Coldwell beds of the Lake District.

The overlying graptolitic fauna occurs in sandy shales, very similar to those of the Upper Coldwell beds of the English Lake district. The Graptolites already enumerated as occurring in the underlying zones are altogether absent from this, and instead of them the following species occur :—

Monograptus colonus, *Barr.*	Monograptus Flemingii (?).
—— bohemicus, *Barr.*	—— testis, *Barr.*
—— Rœmeri, *Barr.*	

Of these, the first is much the most abundant, and is found wherever this division is met with. *M. testis* is very rare and local. The other three I have only seen in the calcareous bands and nodules towards the top of this zone. These calcareous bands also contain other fossils found in the Upper Coldwell beds of Britain, *e. g. Halysites catenularius*, *Ceratiocaris*, *Cardiola interrupta*, many species of *Orthoceras*, &c.

E e 2 has a much richer fauna than E e 1. I think this also may be correlated with the Upper Coldwell beds of the English lakes. It contains, besides the fossils mentioned as occurring at the top of E 1, a great abundance of *Rhynchonella navicula*, which occurs in thousands at Novy Mlyn in the Hlubočep valley. This formation presents a very strong resemblance, both lithologically and palæontologically, to the Wenlock Limestone.

The beds of étages F and G are both correlated by Murchison with the Ludlow rocks (Siluria, p. 380). I think that F 1, however, may be wholly or in part of Wenlock age. If e 2 is to be referred to the Upper Coldwell beds of the Lake district, f 1 could not be newer than the Coniston Grits, or lower part of the Bannisdale Slates, correlated by Mr. Aveline with the Wenlock rocks of Wales. In any case, we cannot make any close lithological comparison of F and G with their British equivalents, for the limestones vary much in thickness in the Bohemian basin itself, and must be viewed as lenticular masses, rather than as deep-sea deposits extending laterally for a great distance. F f 2 has some fossils of a decided Ludlow aspect, such as its large *Pentameri* and its fishes; whilst Goniatites, which are common in G, occur in this étage also.

Étage G presents undoubted affinity to the Ludlow rocks in its fauna; but that fauna is nevertheless a peculiar one, and each of the three bands has its own species.

Étage H has been referred by some geologists to the Devonian series; but M. Barrande has proved that it is Silurian. Its fauna has a remarkable similarity to that of G g 2, and is one of the cases so aptly described by M. Barrande as illustrating migrations, other cases being those of d 1, d 3, and d 5, and of f 2 and g 3. Étage H is probably to be correlated with the passage-beds of Britain; Professor Krejči figures a *Lepidodendron* from this horizon, and it also contains abundance of another plant, *Fucoides hostinensis*. Those who maintain the Silurian nature of some of the Old Red Sandstone rocks of the Welsh border would probably consider H to be on the horizon of those beds.

§ 5. Colonies.

Sir R. I. Murchison (Siluria, p. 380) remarks that "it now appears certain . . . . . that his (M. Barrande's) Second Fauna, the representative of the Llandeilo and Caradoc of Britain, without any mixture of other remains, is superposed to a band containing animals which belong to his Third Fauna, or Upper Silurian;" and a few lines further on, "these alternations of life indisputably connect the Lower and Upper Silurian rocks in one system, through an interchange of a considerable number of their respective fossils." It is needless to describe the theory of M. Barrande: this theory has been attacked by various authors. In 1852 Lipold tried to account for the phenomena in Bohemia by foldings, but afterwards abandoned this explanation. Prof. Krejči afterwards supposed them to be due to faults; both he and Lipold, in letters inserted in M. Barrande's 'Défense des Colonies' (iii. pp. 80, 82), declared that their former ideas on the subject were not correct. In 1868, D'Archiac, from a consideration of certain phenomena in the Carboniferous rocks of Belgium, which had been accounted for by M. Barrande's theory, but afterwards proved to be due to physical disturbances, threw doubt on the theory as applied to the Bohemian phenomena.

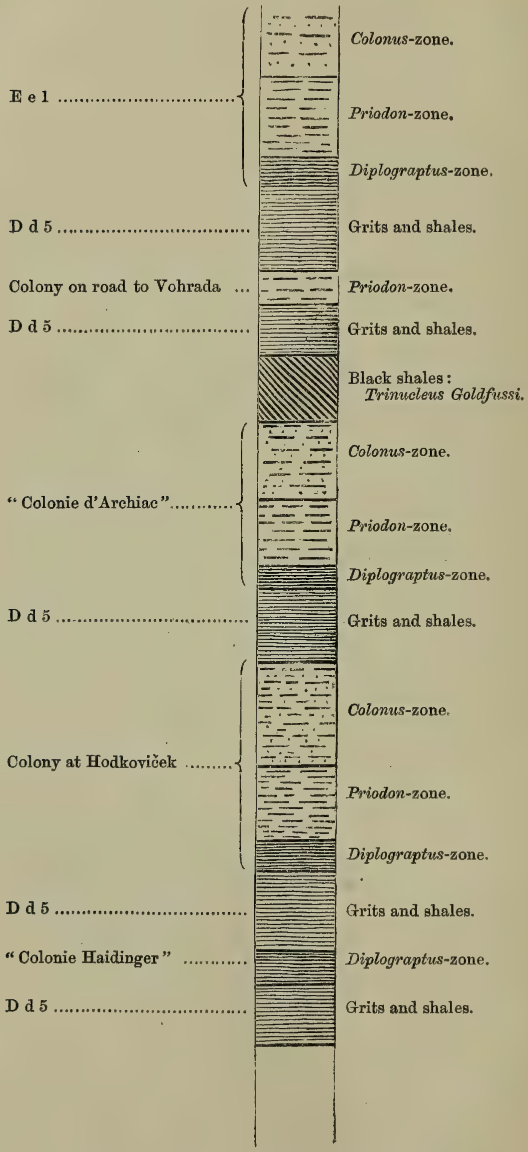
The fauna occurring in the colonies of Bohemia was supposed to have existed in the north of Europe; but this view, as shown by Linnarsson (*cf.* abstract in Geol. Mag. dec. ii. vol. v. p. 282), can no longer be held. In fact it has been shown by Lapworth, Linnarsson, &c. that the Birkhill Shales and their Scandinavian equivalents, which contain a corresponding fauna to that of the colonies, are not to be referred, as was formerly supposed, to the Bala group, but are much newer. Other fossils than Graptolites occurring in the colonies have also been found in Britain, and a table of these is given by Barrande (Défense des Col. iv. p. 131), in which he argues that they all occur in equivalents of his Second Fauna in Britain, that is, in the Upper Cambrian. In analyzing this list, we find the following recorded as Bala:—*Cheirurus insignis*, Beyr., *C. bimucronatus*, Murch.; these do occur at that horizon. *Sphærexochus mirus*; all the specimens from the Bala of Britain referred to this species, which have been examined by Tornqvist, are referred by him to *Sphærexochus angustifrons*, Ang. (Œfvers. af K. Vetenskaps-Akad. Förhandl. 1879, No. 2, p. 70). *Cardiola interrupta*, from the Bala of Coniston; this was when Profs. Harkness and Nicholson considered the Coniston Flags to be Bala. *Atrypa reticularis* and *Strophomena euglypha* are from the Llandovery Rocks. Hence the fauna of the Colonies is by no means to be found in the Upper Cambrian rocks of Northern Europe; on the contrary, it occurs at the base of the Silurian, and therefore it cannot have migrated from the N.W. In fact there is no locality known where this fauna is not characteristic of the base of the Silurian. The same forms of Graptolites occur in Sardinia, as figured by Meneghini; but their horizon is unfortunately unknown.

Nobody now denies the occurrence of migrations, so ably treated of by M. Barrande in the third part of his 'Défense des Colonies,' in which species occur again in beds of the same great group later than those in which they are first found, if the conditions be favourable for their return, but usually mixed with other forms. This, however, is very different from what is required by the theory of Colonies, viz. the characteristic fauna of one great group (the Silurian) existing in another locality in an earlier one (the Cambrian). We know of no such phenomena in any locality whatever, or in any epoch. Why should these colonies occur only in Bohemia (for the phenomena described as colonies in other countries have been all proved to have a different origin)? and why do we not meet with similar phenomena in other parts of the Palæozoic rocks, or in the Mesozoic or Cainozoic epochs?

In describing the characters of E e 1, and comparing this band with its British equivalents, we found that it could, as in Britain, be divided into three zones, characterized by particular Graptolites. The lowest zone, characterized by the genera *Diplograptus*, *Climacograptus*, and *Rastrites*, I shall speak of as the "*Diplograptus*-zone;" the middle, characterized by *Monograptus priodon*, *M. vomerinus*, and *Retiolites Geinitzianus*, as the "*Priodon*-zone;" the upper, with abundance of *Monograptus colonus*, as the "*Colonus*-zone." Now not only are these different zones observable in e 1, but also in the colonies; and although they are not always all three present, still, when more than one occurs in the same colony, they always occur in the same stratigraphical order as that observable in e 1; whilst if we take the whole series of colonies as bands occurring at different horizons in d 5, no such order is observable. This is shown in the following figure (fig. 5, p. 608). In this diagram, which contains only colonies that I have examined, Colonie Haidinger and that at Hodkovičec (on the same horizon as Colonie Krejči) are on the S. side of the basin; whilst Colonie D'Archiac and that on the road to Vohrada are on the N. side. The relative positions are, however, proved by a black band containing abundance of *Trinucleus Goldfussi*, together with *Phacops* (*Dalm.*) *solitaria*, &c., which is very constant in d 5 in this part of the basin, and occurs at some distance above Colonie Krejči, assuming the theory of colonies to be true, whilst it is in contact with Colonie D'Archiac. The colony at Lahovska, which I have not seen, is stated by Barrande (Déf. des Col. iv. p. 58) to be situated apparently between Colonies Krejči and Haidinger. It contains *Monograptus colonus*.

We can hardly conceive such a repetition of the different zones, each in their proper order, in examining one colony, but in no order at all taking the colonies as a whole, and yet the species never becoming intermixed. Further, the lowest zone of E e 1 was before spoken of as being capable of division into subzones, characterized by particular species of Graptolites. This is also the case with the *Diplograptus*-zone in the colonies. Thus the lowest subzone in two colonies which I have examined consists of the peculiar "wafer" shales, crowded with *Climacograptus* and *Rastrites peregrinus*, already described as characteristic of the lowest subzone of the *Diplograptus*-zone of the main mass in E 1. Again, in the only colony which has yielded *Monograptus turriculatus* this species was found in a subzone of the *Diplograptus*-zone, very little below the base of the *Priodon*-zone; this, as before stated, is its position in the main mass of e 1.

Fig. 5.—*Diagrammatic Vertical Section, showing the supposed relations of the Colonies.*



But there is still another difficulty connected with the Graptolites, assuming the theory of Colonies to be true; when the normal beds of d 5 are of such a character as to contain Graptolites, these are of different species from any found in the colonies. In the black shales with *Trinucleus Goldfussi* &c. occurs a species of *Diplograptus* different from any occurring in the colonies or in the beds of e 1. Again, at Kralův Dvůr, near Beroun, in beds fairly high in d 5, and which must surely be above some of the colonies, *Dicellograptus anceps* occurs. Why do these not occur in the colonies also?

Although the shales of the colonies are not favourable for the preservation of higher organisms, the limestone nodules are: one would expect to find some of the characteristic Trilobites &c. of d 5 in these nodules, but nowhere is this the case. In Colonie Zippe, however, occurring in the heart of Prague, M. Barrande records a mixture of species of the second and third faunas occurring in the same pieces of stone. The following list is given (Déf. des Col. iv. p. 115):—

Second Fauna.

Asaphus nobilis, *Barr.*
Calymene incerta, *Barr.*
Phacops (Dalm.) socialis, *Barr.*
Trinucleus Goldfussi, *Barr.*

Third Fauna.

Cheirurus insignis, *Barr.*
Arethusina Koninckii, *Barr.*
Sphærexochus mirus, *Beyr.*
Phacops Glockeri, *Barr.*
Leptæna euglypha, *Dalm.*
—— Haueri, *Barr.*
Spirifer togatus, *Barr.*
Orthis nudus, *Barr.*
Atrypa reticularis, *Linn.*
—— obovata, *Sow.*
Rhynchonella monaca, *Barr.*
—— daphne, *Barr.*
—— sp.

This colony, which is described as a mere lenticular fragment, is not now exposed, and has not, as I am informed, been seen by M. Barrande himself. I may remark that it is exactly in the line of strike of the colony at Motol, and that the beds of d 4, in which it occurs, are about the horizon of the calcareous beds of Vraž before described. May not the colony be a fault-breccia, consisting of bits of limestone of d 4 and E, bound together by a calcareous cement?

Another case of the coexistence of the two faunas at one horizon is given by M. Barrande (Déf. des Col. iv. p. 38); I shall treat of this when describing Colonie D'Archiac.

Besides the palæontological difficulties to be overcome in accepting the theory of colonies, there are also stratigraphical ones. In examining Prof. Krejči's map of the neighbourhood of Prague, it will be seen that the band d 5, in the neighbourhood of Beroun, where there are no colonies, is very much thinner than near Prague, where there are many; and in examining the beds in the field this is found to be chiefly due to the recurrence of great masses of grit in the parts where the colonies occur; whereas when they are absent the beds of d 5 (whether or not they can be divided into an upper gritty and a lower shale division, as proposed by Krejči) consist chiefly of one series of shales and one of grits. But this is just the opposite

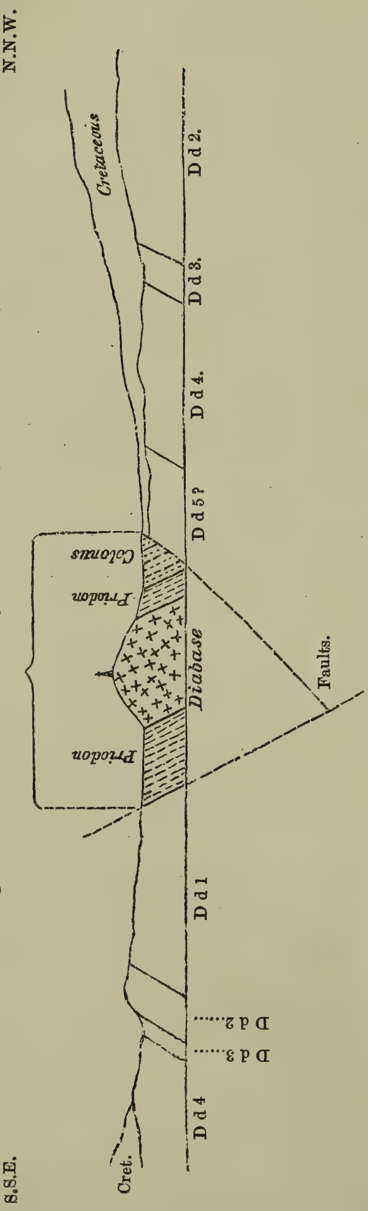


Fig. 6.—*Section across Colony at Motol.* (About 3 miles.)

of what one would expect if the colonies were portions of d 5; for the grits, being evidently deposited in shallow water, should be thickest where the shallow water was most prevalent, and not where deep water prevailed, as shown by the lenticular masses of fine mud &c. which compose the colonies.

On physical grounds, also, it is to be expected that the soft beds of e 1 and d 5 would be crushed and fractured when the hard limestones of the beds above (E e 2, F, G) are folded and faulted in a remarkable manner.

Having described these general objections to the colonies, I shall now proceed to give a detailed account of those colonies which I have examined: first, those on the N.W. side of the basin, viz. the colonies at Motol and Beranka, Colonie Cotta, Colonie D'Archiac, the colony on the road to Vohrada and the one at Tachlovice; secondly, those on the S.E. side, viz. the colony at Branik, that at Hodkoviček, Colonie Krejči, and Colonie Haidinger.

1. *Colonies of Motol and Beranka.*—The colony at Motol is situated about four miles to the west of Prague; it consists of a considerable mass of black shales and limestone nodules, with apparently intrusive diabases. Its actual junction with the surrounding beds is not seen. The section, fig. 6, is taken across this colony, and shows the manner in which I would explain the phenomena. It will be observed that there is a repetition of the older beds to the north of the colony. This indicates a great fault, which, as shown

on Krejči's map, must run through the heart of Prague for many miles in either direction, being continued past Beroun to the S.W. Moreover the beds of the colony dip N.N.W., *i. e.* in exactly the opposite direction to the dip of the neighbouring part of the basin. This seems to point to a trough-fault, which is quite in accordance with the nature of the ground around the colony.

I have seen no traces of the lowest or *Diplograptus*-zone in the colony itself. The *Priodon*-zone is seen on both sides of the high-road close to the village of Motol, near a conical hill surmounted by a cross ; it consists of black shales, with limestone nodules and bands, and contains the following Graptolites :—

Monograptus priodon, *Bronn.*	Retiolites Geinitzianus, *Barr.*
—— vomerinus, *Nich.*	

The *Colonus*-zone is separated from the *Priodon*-zone (just as is the case in undoubted beds of e 1 at Vyskočilka) by limestones. The *Colonus*-zone yielded *Monograptus colonus* in abundance. Other fossils than Graptolites occur in the limestones of the colony, among which Dr. Novák has discovered *Arethusina Koninckii*, preserved in the Museum at Prague. This is a well-known Trilobite of E in Bohemia, and the genus is not, so far as I am aware, known in any other country.

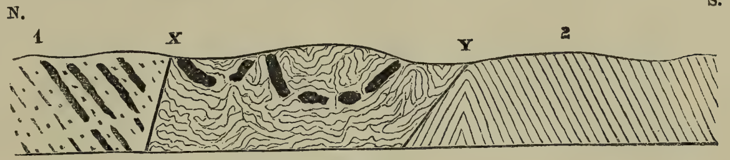
The colony at Beranka is a continuation of that at Motol, to the W. of the latter, and contains the *Priodon*-zone.

It has been already mentioned that the fault which would bound these colonies would also pass through the little lenticular mass in Prague, named Colonie Zippe.

2. *Colonie Cotta.*—This is to the S.S.W. of Jinonice, between Prague and Řepora, and about two miles to the south of the last-described colonies. It merely exhibits a mass of diabase rising out of alluvial deposits, and including baked sandy shales with *Monograptus colonus* in abundance. It is on the line of strike of the colony about to be described.

3. *Colonie D'Archiac.*—Situated about two miles S.W. of the last described. There is no good rock-exposure betwixt the two colonies. I was fortunate enough to examine that under consideration, along with Dr. Novák, just after a section had been exposed along a road-cutting, and this showed clearly the relations between the "colony" and the surrounding beds. In M. Barrande's map of this colony (appended to Déf. des Col. iv.) a mass of diabase is shown crossing the road to Třebonice, between the colony and the beds of d 5 to the S.E. of it. This mass does not appear in the road-section, and at this point a clear exposure is exhibited, as shown in the following figure (fig. 7). In this section the beds between X and Y were contorted in every possible manner. A calcareous band containing *Monograptus colonus* &c. occurred, much folded, near one corner of this mass, and above it were blackish sandy shales, similar to those of the top of the colony. Below were black and olive-green shales, with little nodular concretions, like those of d 5, and containing fragments of fossils. The relations of the beds above

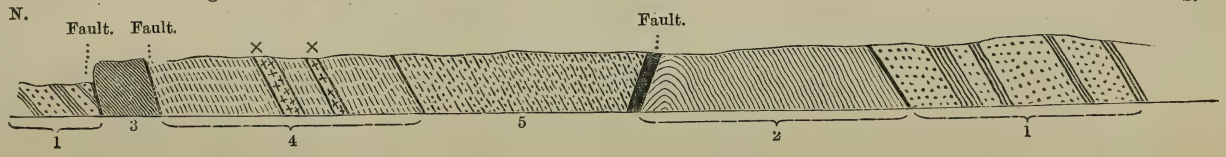
Fig. 7.—*Section across Fault at S. end of "Colonie D'Archiac," Řepora.*



1. *Colonus*-zone, at top of colony. The black bands are limestone.
2. Black shales: *Trinucleus Goldfussi*, &c.

Between X and Y a fissure filled with contorted and broken shales of D d 5 and E e 1. The black band at the top consists of limestone band of E e 1 with *M. colonus*, &c. The fissure is several yards in width.

Fig. 8.—*Section across "Colonie D'Archiac," Řepora.* (Length about $\frac{1}{4}$ mile.)



1. Green grits and shales. } D d 5.
2. Black "*Trinucleus*" shales. }

××. Diabase.

3. *Diplograptus*-zone. } Shales of Colony.
4. *Priodon*-zone. }
5. *Colonus*-zone. }

and below are shown in the larger section across the colony itself (fig. 8). There is no alternative but to consider the mass between X and Y as filling up the fissure of a fault; for the black *Trinucleus*-shales, at their southern extremity, are succeeded by the usual green shales and grits of d 5, of which there is no trace here, and the idea of an unconformity is negatived by the smashed nature of the rock.

This section would also account for the coexistence of the two faunas at one horizon described by M. Barrande (Déf. des Col. iv. p. 38) as occurring at the summit of this colony, and before alluded to. As will be seen by the section, there are at least two other faults in connexion with the colony, which are seen in clear exposures.

The palæontological evidence of this "colony" is as satisfactory as the physical, the three zones of Graptolites being easily made out. The lowest, or *Diplograptus*-zone, is bounded by faults on either side, that between it and the shales of d 5 being a perfectly clean-cut fracture, whilst the one above, dividing it from the *Priodon*-zone, is marked by a fissure filled with fault-rubble. The lowest subzone of the *Diplograptus*-zone is alone to be seen in the roadside cutting. It consists, as usual, of "wafer shales" crowded with *Climacograptus scalaris* and *Rastrites peregrinus*. It yielded to a short search:—

Monograptus Becki, *Barr.*
Rastrites peregrinus, *Barr.*
Diplograptus folium, *His.*
Diplograptus tamariscus, *Nich.*
Climacograptus scalaris, *His.*

The *Priodon*-zone is, as usual, a black flaggy shale, containing bands and nodules of limestone. The included igneous rocks are well described by M. Barrande in his 'Défense.' The Graptolites obtained were:—

Monograptus priodon, *Bronn.*
—— vomerinus, *Nich.*
Monograptus, sp.
Retiolites Geinitzianus, *Barr.*

The *Colonus*-zone is a sandy black shale, weathering yellowish, and containing limestone bands and nodules. I obtained:—

Monograptus colonus, *Barr.*
—— bohemicus, *Barr.*

I also obtained *Naticella tubicina* and *Peltocaris*? from a nodule in this zone.

4. *Colony on the road to Vohrada.*—This lies between Colonie D'Archiac and the main mass of e 1. Between it and the last described lie the *Trinucleus*-shales, and green shales and grits of d 5, whilst between it and the main Silurian mass are green shales and coarse green and yellow grits. It seems to consist of shales included in diabase, and I was unable to find any fossils in it; but M. Barrande (Déf. des Col. iv. p. 41) records *Monograptus priodon*, Bronn, and *Retiolites Geinitzianus*, Barr. No section is seen showing its relations to the surrounding beds.

5. *Colony at Tachlovice.*—The present colony occurs some miles to the W.S.W. of Colonie D'Archiac, in the village of Tachlovice. Its eastern extremity is not seen, owing to overlap of Cretaceous

rocks and drift. It may possibly be an extension of Colonie D'Archiac. There is no exposure showing the junction of the beds of the colony with those of d 5 to the S. of it. To the N. green shales are seen in conjunction with black Graptolitic shales, near some houses to the N. of the church. These green shales, however, do not appear to belong to d 5, but to be interstratified with the Graptolitic shales, as at Litohlav. They contain poorly preserved Graptolites. I was unable to procure any specimens from this colony sufficiently perfect for identification.

To the S. of the Silurian basin, passing from E. to W., the first colony met with is

6. *Colony of Branik.*—This is not now exposed, although the diabases connected with it are well seen in the village of Branik, on the E. side of the Moldau, two or three miles south of Prague. The colony is surrounded by alluvial deposits. The only Graptolites found by M. Barrande belong to the species *Monograptus colonus*, Barr. They occur in a sandy and calcareous shale.

7. *Colony at Hodkoviček.*—This occurs to the S.W. of that last described and near the river Moldau. Diabases connecting the two colonies can be traced, by their features, passing through the alluvial deposit. The figure (fig. 9) shows a section across this colony; the faults to the N.W. are seen in a small quarry. Only the upper part of the lowest (*Diplograptus*) zone is exposed; it is in close proximity to the base of the *Priodon*-zone. It consists of black mudstones, breaking into prismatic fragments, and containing

Monograptus spinigerus, *Nich.*
—— Becki, *Barr.*
Monograptus triangulatus, *Harkn.*
—— turriculatus, *Barr.*

In the *Priodon*-zone are many masses of diabase. A large quarry facing the river shows this zone; it consists of black flaggy shales, containing

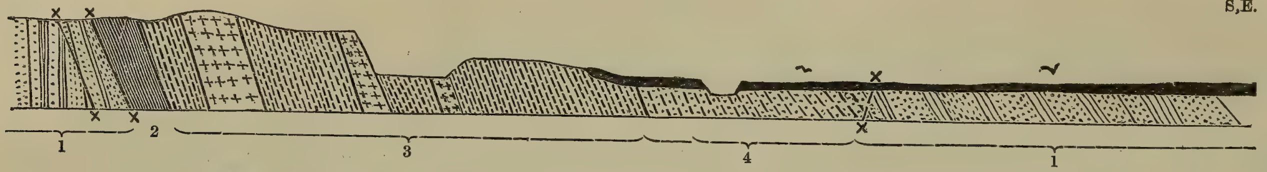
Monograptus priodon, *Bronn.*
—— vomerinus, *Nich.*
Retiolites Geinitzianus, *Barr.*

The *Colonus*-zone was seen, at the time of my visit, in a small gravel-pit in the alluvial plain; it consisted as usual of sandy shale, weathering to a yellowish brown, and contained numerous specimens of *Monograptus colonus*, Barr. No fault is seen, as the section is covered by the alluvial soil; but the dotted fault, if existing, would give sufficient explanation of the phenomena observed in this locality. Unfortunately we cannot get any direct evidence of its existence, for before the alluvial soil ends to the eastward, a large N. and S. fault (the Branik fault of Barrande) would cut it off.

8. *Colony Krejči.*—This colony, which is seen in a cliff-section to the south of the village of Gross Kuchel, is in the line of strike of the colony at Hodkoviček, from which it is distant more than a mile, the Moldau with its alluvial plain intervening.

I could not, during my short stay in Bohemia, form any certain opinion of the explanation of this colony. The section is described by M. Barrande (Déf. des Col. iv. p. 60). His upper band of trap

Fig. 9.—*Section across "Colonie de Hodkoviček."* (Length about 200 yards.)

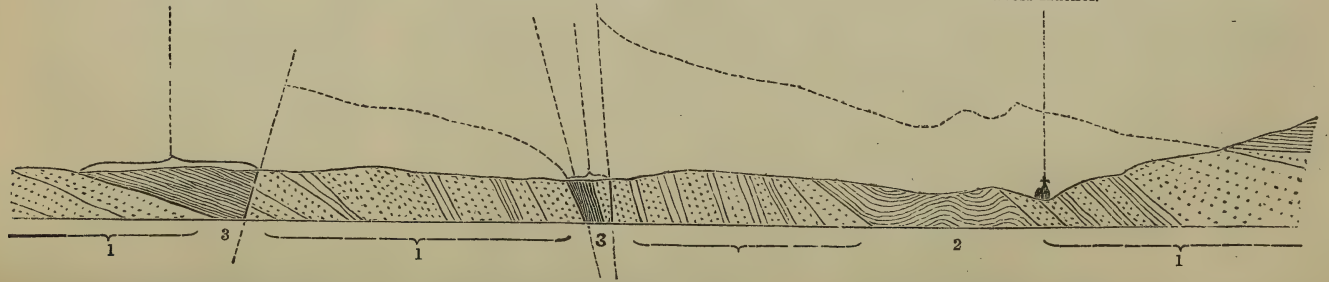


1. Grits and shales, D d 5.
2. *Diplograptus*-zone.
3. Diabase. *Priodon*-zone.
4. *Colonus*-zone.

(2–4: E e 1.)

∽ ∽. Alluvial plain of Branik.
× ×. Faults.

Fig. 10.—*Section across "Colonies Krejči" and "Haidinger."* (Length about 1 mile.)



1. Grits and green shales. 2. Black "*Trinucleus*" shales. 3. Graptolitic shales of E 1 and "Colonies."

is only seen at the summit of the cliff, and does not occur at the bottom. The junction between this part of the colony and the beds of *d* 5 is distinctly shown. The beds of the colony are here nearly vertical; those composing the main mass are blackish sandy shales, weathering yellowish brown. At what M. Barrande considers the top of the colony, there are nodules of limestone and some bands of calcareous grit very much disturbed, and these are not continuous, but abut in places against the beds of d 5. This might be due to an unconformity; but I considered it to be due to a fault, which must have a very clear fracture. A fault, moreover, would account for the disturbance of the beds, which an unconformity does not. This fault would be continuous with that supposed to let down the beds forming the colony at Hodkovičck; it is, however, here slightly reversed. The limestone nodules yielded the following Graptolites:—

Monograptus colonus, *Barr.*	Monograptus Rœmeri, *Barr.*
—— bohemicus, *Barr.*	—— Flemingii ?

These, along with *Cardiola interrupta*, *Naticella tubicina*, &c., indicate distinctly the *Colonus*-zone. At the other end of the colony is a fracture indicated by a small spring which trickles down a mossy hollow in the side of the cliff and contains pieces of a fault breccia. On the other side of this again are grits of d 5 and also some black shales, not very well exposed, and in which I found no fossils, but which I believe belong to the *Diplograptus*-zone, for M. Barrande records *Diplograptus palmeus*, Barr. (=*folium*, His.), from this colony. It seems to me, then, that the colony was produced in the same manner as that at Hodkovičck, of which it is probably the continuation, but that after its formation the second fracture occurred, cutting off some of the *Colonus*-zone, all of the *Priodon*-zone, and most of the *Diplograptus*-zone, and giving the first fault its slight reversal.

At the summit of the cliff-section exhibiting this and the next colony is a tableland covered with corn-fields, so that the colonies here cannot be traced along their strike to the S.W.

9. *Colonie Haidinger.*—A mass occurring in the same river-cliff with Colonie Krejči, and a few hundred yards to the S.S.W. of the latter. Its section is described by M. Barrande (Déf. des Col. iv. p. 59). It consists entirely of the black "wafer" shales characteristic of the base of the *Diplograptus*-zone. I saw the outcrop of a clean-cut fault between it and the beds of d 5, which are supposed to surmount it. I consider this colony, then, to be the lowest subzone of the *Diplograptus*-zone at the base of e 1 faulted down against the beds of d 5. I give a section from the Silurian base of the Slivenec valley, across colonies Krejči and Haidinger, showing the view entertained as to the explanation of these colonies (fig. 10, p. 615).

M. Barrande records only Graptolites from Colonie Haidinger (Déf. des Col. iv. p. 60). By the kindness of Herr Dusl of Beroun, I have been enabled to make a larger list of fossils, all of which, save one, are in the magnificent collection of that geologist. Many of the species have not hitherto been recorded from Bohemia; some of them have been found by myself at the base of the main Silurian beds; and others would I feel sure be found if searched for. The list is as follows :—

Monograptus spinigerus, *Nich.*	Diplograptus Hughesii, *Nich.*
—— triangulatus, *Harkn.*	—— folium, *His.*
—— Becki, *Barr.*	—— cometa, *Gein.*
—— cyphus, *Lapw.*	—— tamariscus, *Nich.*
—— tenuis, *Portl.*	—— sinuatus, *Nich.*
—— proteus, *Barr.*	Climacograptus scalaris, *His.*
Rastrites peregrinus, *Barr.*	Discinocaris Browniana, *Woodw.*
—— capillaris, *Carr.*	

All these fossils, including the *Discinocaris* of which Herr Dusl possesses three specimens, are characteristic of the Birkhill Shales of Britain.

§ 6. Summary.

In very many of the Predevonian rocks of Bohemia we find marked lithological resemblances to the corresponding horizons in Britain.

The Precambrian series is divisible into two distinct groups, similar to the Dimetian and Pebidian groups of Britain, and lying unconformably to one another and to the overlying Cambrian rocks.

The beginning of the Cambrian period is marked, as in Britain, by a coarse conglomerate, which is probably of later formation than that of our own island, although it is probably homotaxeous with it. Moreover, there are strong resemblances between the various bands of the Bohemian and British Cambrian beds, especially marked in the deeper water deposits. The palæontological similarities are in many cases not so striking as the lithological.

In the Silurian period, the resemblances, both lithological and palæontological, between Bohemia and Britain were less striking than in the Cambrian. The limestones so abundant in the Bohemian series seem to be lenticular masses having no wide extension; the most regular limestone is that of E 2, and this is about the horizon of, and comparable with, the Wenlock Limestone. But although the beds of this period as a whole are not so strictly comparable in the two countries as those of the Cambrian, we nevertheless find most remarkable coincidences between the zones of the lowest band, *i. e.* the Graptolite-bearing shales.

The igneous rocks do not present many unusual features; but the occurrence of mica-traps in the Cambrian beds is very noteworthy, limited as they are, so far as yet known, to Predevonian rocks.

Objection may be raised to my using Prof. Sedgwick's nomenclature for the rocks of a region which M. Barrande has so conclusively shown to possess three well-marked faunas. But the foregoing observations seem to show that the break between the upper and middle faunas is much more marked than that between the middle and lower. In the first place, the deposition of the Cambrian beds does not seem to have begun over the whole area until the close of the Primordial era, the rocks containing the Primordial fauna, as well as the underlying conglomeratic series, being only locally developed, whilst it is not until the overlying beds of d 1 α that any thing like continuous deposition appears to have set in. Again, if I am right in referring d 1 α & β to the Lingula Flags and Tremadoc Slates respectively, the unconformity between the Primordial zone and second fauna of Bohemia does not occur at the same horizon as that between the Primordial zone and overlying beds of Britain, for the equivalents of d 1 α & β are included in the Primordial beds of Britain, or Cambrian of Sir C. Lyell, Dr. Hicks, and Mr. Lapworth. The break between the second and third faunas of Bohemia, on the other hand, occurs at the same horizon as in Britain, viz. between the top of the Bala beds and the Graptolitic fauna of Birkhill age. Lastly, the beds of d 1 α & β have as yet yielded by no means a satisfactory fauna, so that we do not here get one fauna in beds *immediately* succeeding another, as is the case with the beds at the top of the second and base of the third faunas of M. Barrande.

But the connecting link between these two latter periods was supposed to have been discovered in the colonies of M. Barrande. I feel justified in saying that I have brought forward sufficient evidence to warrant a reconsideration of the data on which the theory of colonies was founded, and to give some grounds for the supposition that they are only portions of the band e 1 faulted down among the grits and shales at the summit of the Cambrian series.

Discussion.

The President said that Mr. Marr was the first person who had attempted to correlate the Tremadoc, Arenig, and Bala beds of Britain with those of Bohemia. It was very difficult to understand the existence of these colonies. In Britain we have no recognized colonies; but repetition of species occurs in some of the Secondary rocks. The lists of fossils contained in Mr. Marr's paper were of great value.

Prof. T. M'K. Hughes said that the difficulties under discussion arose from not checking the palæontological by the stratigraphical evidence, and thought that we had in Mr. Marr's paper a most valuable contribution by a very competent observer. In considering the question he would inquire (1) What is the ordinary manner of appearance of the various forms of life? and (2) Have we experience in any clear case of that exceptional mode of occurrence described by the distinguished author of 'The Theory of the Colonies'? As to (1), he thought that new genera and species came in gradually, owing to changes in the conditions affecting life in adjoining areas, and that, after a similar interval, whether measured by the thickness of continuously deposited strata or by the thickness of missing deposits in the case of an unconformity, we observe about the same kind of difference in the general facies of the forms of life. As to (2), the appearance of a group of fossils resembling the group in another part of the series in the same district with a different group in the intermediate beds was, in his experience, very rare. The only case at all like it that he knew was on the borders of Yorkshire, where a group of fossils occurred in a band low down in the Coniston Grit; and though the species were all found here and there scattered through the series, the *group* was only seen again in that area 7000 feet higher in the series. But this was quite a different case from that of the colonies now put before them, and he thought the recurrence three times of the three zones in the same order a coincidence too remarkable to be received without the clearest stratigraphical evidence.

Prof. Judd said he had some years ago had the opportunity of examining the district, and he thought the conclusion could not be avoided that M. Barrande had been more successful in the palæontological branch of his work than in the stratigraphical. In the former he was quite unrivalled; but in the field he appeared, during recent years, to have trusted more to others than himself. It was obvious on examination that the beds were much disturbed and required much careful mapping.

Dr. Hicks expressed his high appreciation of the paper. He felt quite convinced by the author's reasoning. The author had not only given him all the beds he had at St. Davids of Cambrian and Silurian age, but Pre-Cambrian also. He fully believed that the colonies were only repetitions by folds and faults.

Rev. J. F. Blake said that in studying Silurian Cephalopoda the colonies proved a great trouble because we did not find Lower Silurian forms associated with Upper Silurian. The Cephalopoda in the colonies, not found in the Lower Silurian, are more allied to the English Upper Silurian.

Mr. Marr said that he was much gratified by the way in which his paper had been received. A case which had been mentioned as somewhat parallel in the Lake district was hardly so, as the supposed Ludlow fossils were also Wenlock. M. Barrande, of late years, had had his attention diverted from the Graptolites, and so had not been able to make use of Mr. Lapworth's researches.

43. Faröe Islands. Notes *upon the* Coal *found in* Süderöe. By Arthur H. Stokes, Esq., F.G.S., one of H.M. Inspectors of Mines. (Read June 23, 1880.)

In the following paper I have the honour to lay before the Society the result of a recent exploration of the coal-seams found in Süderöe, one of the Faröe Islands.

In the summer of 1873 (a few months before my connexion with H.M. service commenced) I visited Süderöe for the purpose of reporting upon this coal-field. During my leave of absence from official work this summer (1879) I again visited the island, and also two other islands forming part of the group called Faröe. The island to which this paper specially refers is the most southern, and lies in the parallels of latitude 61° 25′ and 61° 42′, occupying a geographical extent of about 20 miles by 5 miles.

Any paper bearing upon the extension of the area of coal-seams within reach of countries using that fuel must possess peculiar interest, and the details of some observations made in a recent visit to Süderöe may not be uninteresting to the Members of this Society.

The position of the coal-fields will be best understood by reference to the map (p. 621), the shaded part indicating the extent, or area, under which coal is found.

Qvalböe Mines.

The coal in this district is already being worked by the natives of Süderöe by means of adits driven in the coal from the mountain-side. There are six adits now used for getting coal; but for a distance of about 900 yards numerous old adits can be traced, and the place whence they were driven is clearly distinguishable, although the entrances are completely closed by débris. The date at which the coal was first worked could not be ascertained. It probably commenced soon after the first settlement of the inhabitants; but as peat is plentiful, and easily obtained, the coal is only worked for a few of the inhabitants of the small village of Qvalböe, none of the coal being worked for exportation, and the total quantity wrought during the summer being only a few tons.

I visited these mines in 1873, and again in 1879; at both visits I found men getting coal for the winter's supply. The working-places are very irregularly driven; starting first from the mountain-side with an adit of about 5 feet wide, they soon increase to 12 feet wide, and at intervals "thirl," or make communication into the old works. They do not proceed far under the mountain, but prefer to commence in another place rather than drive a long distance from the mouth of the adit. No one system of work is carried out, but the places are driven at the pleasure of the men getting the coal. The whole of the mining-operations are carried on in the most primitive manner.


SUDEROE
FAROE ISLANDS.
Ornenipen
QUALVIG
Norbes Eidet
QVALBOE
QUALBÖ FJORD
Quanhave Bund
COAL AT SEA LEVEL
Frodbö Bund
TRANGISVAAG FJORD
TVERA
ORDEVIG
FAMOYEN
HOVE
HOVE BUGT
PORKERI
Famarasund
COPPER FOUND HERE
VAAG
NÆS
VAAG FJORD
LOBRO
Vig
ATLANTIC
ATLANTIC OCEAN
Area under which Coal is found shaded thus
Excavations to prove Coal
SCALE OF MILES.
0 1 2 3 4 5 Miles.
Longitude 7° West of Greenwich.
61 40
61 30

The tool used by the men for getting the coal was a small iron hack, which, from examination, appeared as if it was only sharpened once a year to get the annual stock. The light used consisted of a small wick of home-spun wool, fed with whale-oil, depending from one side of a circular piece of tin similar to a common tea-saucer.

The coal is transported from these mines by both men and women, who carry it upon their backs in small wooden boxes.

The roof of the mine is good. There are no indications of the roof having ever weighted or broken above the coal; this is probably due to the small area worked, and that directly the adit is entered there are some hundreds of feet of trap rock covering the coal. No timber or trees of any description are grown upon the island; hence it would be difficult to obtain wood to support the roof, except by importing pit-props.

There is very little water found in the mines, and the adits being driven from the mountain-side, what water is found runs away and falls into the valley below.

Of various sections taken in these mines the following two may be regarded as representing the average thickness of the seam.

(1) Height 120 metres above sea-level.

	metre.	
Coal	0·37	
Argillaceous shale	0·54	
Coal	0·15	Now being worked.
Argillaceous shale	0·15	
Coal	0·21	
Argillaceous shale	0·15	
Coal	0·41	

(2) A section taken about north-east from the above, in another adit or mine, was as follows:—

Height 113 metres above sea-level.

	metre.	
Coal and argillaceous shale (about 50 per cent. coal)	0·40	
Coal	0·20	
Argillaceous shale	0·39	Now being worked.
Coal	0·20	
Argillaceous shale	0·14	
Coal	0·57	
White clay (thickness not known).		

Area of Coal-fields.

Previous to the year 1872 the above was about all that was known with regard to these coal-seams; but the Danish Government having granted a concession of the coal found on this island, further exploration was made; and when I visited it in 1879 I found that the full area of the coal-seams had been proved by numerous openings made all round the mountains under which the coal-seams rested. These points are indicated by numbers and points on the map, and will be referred to in describing each opening and its section.

No. 1. 20 *metres above sea-level.*—At this point a small adit has been driven into the mountain-side for about 14 yards, and a thin seam of coal has been worked by one of the inhabitants.

No. 2. 68 *metres above sea-level.*—This is a small opening made in the mountain-side and exposes to view a seam of coal 0·34 metre thick; but the thickness of the coal-bearing strata is not proved.

No. 3. 120 *metres above sea-level.*—This is similar to No. 2. About 3 metres in depth of ground has been opened out, and 5 small seams of coal, from 0·07 metre to 0·12 metre thick, found; probably the thicker seams are either above or below.

No. 4. 212 *metres above sea-level.*—At this point a small heading, or adit, has been driven in the coal-seam, with the following section:—

	metre.
Coal	0·37
Argillaceous shale with small coal-seams	0·41
Coal	0·21
Soft clay	0·17

No. 5. 239 *metres above sea-level.*—This is the almost perpendicular side of the mountain next the Atlantic. A heading has been driven in the coal-seams about 8 metres in length, and at the end of this heading I took the following section:—

	metre.
Coal (bright hard coal)	0·30
Argillaceous shale	0·62
Coal	0·19
Argillaceous shale	0·20
Coal	0·34

At a vertical depth of 13 metres below this heading two seams of coal were found of 0·44 metre and 0·15 metre thick respectively, with 0·60 m. of argillaceous shale between them. It is my opinion that the section given above, represents the seams worked in the Qvalböe mines, and that these lower seams probably lie under the coal now being worked in the Qvalböe valley.

No. 6. *About* 220 *metres above sea-level.*—This is inaccessible, it being a perpendicular cliff, and can only be reached by a rope from the rocks above; but it can, in calm weather, be approached on foot within 50 metres, and then is seen the full thickness of the coal-bearing strata, which I judged to be about 15 metres, with hundreds of metres of trap rock above, and a similar rock below to the sea-level.

No. 7. 8 *metres above sea-level.*—Two headings, or adits, have been driven in the coal-bearing strata at this point; but very little coal being found, it was abandoned. There is, however, one curious phenomenon noticed at this place, viz. a small seam of coal 0·04 metre thick, and directly upon the top rests trap-rock without any other rock intervening. In places the surface of the coal next the trap-rock appears burnt, as if an igneous rock had, whilst hot, flowed over it. I noticed this in more than one place, and found similar pieces near No. 4 in 1873.

No. 8. 249 *metres above sea-level.*—This is on the southern side of the Trangisvaag valley, and consists of a heading driven in the coal-seam for about 30 metres, at the end of which a good section is exposed to view.

	metre.
Argillaceous shale	0·13
Coal	0·07
Argillaceous shale	0·39
Coal	0·16
Argillaceous shale	0·42
Coal	0·23
Argillaceous shale	0·71
Coal	0·63
Argillaceous shale	0·21
Coal	0·11
Argillaceous shale	0·20
Coal	0·20

It would be entering into too minute details to give all the sections taken; and therefore the author has indicated upon the map the whole of the positions where the coal-bearing strata have been discovered, and given a tabulated epitome of such sections as are required to prove their continuity.

It is very clear, from the sections and heights of the various openings made in the mountain-sides, that the whole of the seams of coal are those included in the thickness of argillaceous shale which exists between the trap or dolerite mountains, as previously named in describing No. 6 section. At no other point could I find a place where the total thickness of the coal-bearing strata could be measured.

The mountain-sides present to the eye a number of parallel layers of trap, extending for miles in successive beds; the regularity of these beds, and their horizontal position, running in unison, may be traced from the mountain-top until they gradually descend to the sea-level. They have one uniform dip and direction, stretching from S.S.W. to N.N.E., and fall towards the N.E. at an angle of from 3 to 4 degrees.

The heights of the various openings made to expose the coal-seams are given above sea-level, and were taken by means of an aneroid barometer. The instrument was adjusted to sea-level before starting in the morning, and again upon return in the evening, the time of each observation correctly entered with the barometrical reading, and alterations allowed for in the working-out of the observations after each day's journey.

It will be seen upon reference to the map that the coal-field is divided into two districts, the Trangisvaag valley separating the northern from the southern coal-field.

It is not only possible, but very probable, that this was at one time one unbroken coal-field, and that the part forming the Trangisvaag valley was washed away after the coal-bearing strata had been deposited. The coal on either side of the valley being so similar in character, and its inclination agreeing in both dip and direction, there can be but one opinion formed by those who have seen the strata, viz. that it is one and the same formation.

The area of the coal-fields or, more properly speaking, coal-bearing strata (because it is not yet definitely ascertained that a good workable seam or seams extend under the whole of the district, although it is very probable that such a seam or seams do exist) is about 5500 acres, viz. the northern district about 5000 acres, and the southern about 500.

Coal has been found in isolated places in other parts of the island, but in quantities so small as to require little notice as regards commercial value.

Quality of Coal.

There are two sorts of coal found in the seams—one a bright hard coal, breaking with a conchoidal fracture, very hard, and at times presenting a woody structure; in outward appearance it is very similar to cannel coal. The other coal is like ordinary English house-coal, breaking in parallel lines of fracture, presenting a bedded structure and not so hard as the first named. The whole of the seams may be termed coal of the Lignite quality; and its commercial value will be best understood by giving an analysis of both kinds of coal.

	Bedded coal.	Bright pitchy coal.
Carbon	51·71	68·20
Hydrogen	4·49	5·02
Ash	25·70	2·48
Oxygen and Nitrogen	18·10	24·30
	100·00	100·00

The calorific value, taken by Thompson's apparatus, gives the amount of water converted into steam by 1 lb. of the coal as follows:—

	lb.
Bedded coal	9·35
Bright pitchy coal	9·60

Population.

The population of the whole island is about 2000 persons. The natives of Süderöe are by occupation fishermen, and the great quantity of peat which lies within a few yards of their dwellings is an additional reason for their taking very little interest in the coal.

The population of the small villages near the coal-fields was as follows in 1873:—

Trangisvaag	143
Tverra	83
Frodebo	101
Ordevig	88
Qvalböe	362
	777

Working of the Coal.

Should the coal be worked in large quantities, either for the islands or for exportation, it would be necessary to import nearly the whole of the labour required; the Faröe men would be more troublesome than useful.

The coal-seams lie so favourably for working that no shafts would be required; and the whole of the district I have explored could both be unwatered and worked by adits or drifts driven from the mountain-side.

The result of my exploration has been the confirmation of the reported existence of a large area of coal-bearing strata, the details of which, I trust, will be not only interesting to the Fellows of this Society, but be placed upon record for future reference when the geology of these interesting islands may be studied by others far more able to deal with the subject than the author of this paper.

Sections.

No. 9. 265 metres above sea-level.

	metre.	
Argillaceous shale.		Inclination 7° N.N.W.
Coal	0·68	
Argillaceous shale	0·12	
Coal	0·13	
Argillaceous shale with very small bands of coal	0·90	
Light-coloured argillaceous shale.		

No. 10. 325 metres above sea-level.

	metre.	
Argillaceous shale.		A few yards from this point are to be seen old coal-workings, stated to have been worked by Norwegians.
Coal and argillaceous shale in layers	0·22	
Blue argillaceous shale	0·23	
Coal	0·20	
Blue argillaceous shale	0·51	
Coal	0·12	

No. 11. 225 metres above sea-level.

	metre.	
Trap rock.		One seam of coal 0·11 metre, and another 0·07 metre of good bright coal.
Schistose rock	·05	
Coal and argillaceous shale mixed	1·00	

At this point a heading or adit was driven many years ago by the Norwegians for getting coal.

No. 12. 322 metres above sea-level.

	metre.
Argillaceous shale.	
Coal with a few thin bands of argillaceous shale	0·86
Light-coloured clay	0·05
Argillaceous shale	0·30
Coal	0·32
White clay.	

This is found nearly at the summit of one of the mountains, and is only of very small area.

No. 13. This is very similar in extent to No. 12, being a small area of coal-bearing strata at an almost inaccessible height up one of the mountain-peaks.

44. *Note on the* Cranial Characters *of a large* Teleosaur *from the* Whitby Lias *preserved in the* Woodwardian Museum *of the* University *of* Cambridge, *indicating a new Species*, Teleosaurus eucephalus. By Professor H. G. Seeley, F.R.S., F.G.S., &c. (Read June 23, 1880.)

[Plate XXIV.]

The Woodwardian Museum of the University of Cambridge has long contained the cerebral region of the skull of a large Teleosaur from the Lias of Whitby, which differs in important characters from the Teleosaurs hitherto described, and adds some interesting points to our knowledge of the cranial characters in this extinct suborder of animals. Attention was briefly drawn to the specimen at p. 121 of my 'Index to the Fossil Remains of Reptilia &c. in the Woodwardian Museum,' 1869. The skull has been transversely fractured anteriorly, posterior to the suture between the parietal and frontal bones, so that no part of the frontal region is preserved, and therefore no indication is given of the anterior expansion of the skull beyond the long temporal fossæ. The crest of the parietal bone appears to have been more than usually wide and strong, but that, too, is imperfectly preserved. The quadrate and squamosal bones are broken away at the sides; the base of the occipital region is fractured, and the pterygoid bones are absent; but the very imperfections of the specimen led to its being sawn through in the median line, so as to display a vertical section of the brain-case. Care has been taken to make the section so as to throw light on the lateral modifications of the brain-case; and I now venture to submit to the Geological Society some account of the characters thus displayed. In existing Crocodiles the brain-case is relatively small, owing to the shortness of the parietal region, and it is imperfectly closed anteriorly; here it is much longer and larger in proportion and closed by bone in front. The thickness removed by cutting and polishing the cerebral section makes the right half of the skull about half or three quarters of a centimetre narrower than the left half.

On the left side (Pl. XXIV. fig. 1) the extreme length of the fragment, from the basioccipital articular surface to the anterior fracture, is about 19 centimetres; the extreme depth of the specimen as preserved is about 12 or 13 centimetres; the brain-cavity is narrow and about 14 centimetres long, but on this side appears to have extended anteriorly a little beyond the extremity of the bone. The termination of the brain-cavity is 2 centimetres deep, and 8 millimetres in transverse width, as seen on the anterior fracture, where the outer margin is convex. The cranial cavity is long, and has its superior and inferior walls slightly diverging as they extend backward. At a distance of $1\frac{1}{2}$ centimetre posterior to the anterior fracture the depth increases to more than 3 centimetres, and the base and roof of the brain continue nearly parallel to each other for between 6 and 7 centimetres. The cause of the sudden anterior decrease in depth is that a large nerve 8 millimetres thick is given off at the anterior end of the brain, in the median line; and this, according to analogy, I regard as being the olfactory nerve (fig. 1, *olf*). At the distance of about 6½ centimetres backward a slight angular bend occurs in the roof of the brain-case, so that it increases in height for the next 4 centimetres as it extends backward. This part of the roof is straight; the anterior part is very gently arched. Below the point where this angle occurs is the entrance to the pituitary fossa (*pf*). The depth from the roof of the brain-case to its base is 6 centimetres. The pituitary fossa extends backward under a strong forwardly directed process of the sphenoid bone, and from it a canal is prolonged forward, which becomes a little narrower as it extends below the canal for the olfactory nerve, from which it is separated by a thickness of a centimetre of bone. This nerve I regard as the optic (fig. 1, *op*). The base of the brain-cavity from the sphenoid to the superior extremity of the basioccipital, where the spinal cord enters the skull, is gently concave in length. At 10½ centimetres from the anterior end of the specimen a slight bony process descends downward and forward from the roof of the brain-case, as though to make a posterior termination to the cerebrum. At this point the depth of the brain-case is about 4½ centimetres; a narrow excavation appears behind this process, not more than a centimetre wide, and rather compressed above, as though marking the position of the optic lobe of the brain (*o*). Posterior to this the roof of the brain-case, which is convex in length, descends rapidly to the foramen magnum (*FM*), which is less than 2 centimetres high. This constriction I take to indicate the relatively small size and depressed shape of the cerebellum (C^m). Posterior to the brain-cavity the superior concave neural surface of the basioccipital bone (*Bo*) extends backward for 2½ centimetres; so that, in its median line, the brain-case is remarkable for the comparative parallelism of its inferior and superior margins, disturbed mainly by the elevation of the optic lobes and hinder part of the cerebrum and by the depression of the cerebellum.

It will now be convenient to describe the characters shown on the right side of the section, fig. 2. Notwithstanding the comparative thinness of the vertical layer which has been removed from this side, the brain-case is only 11 centimetres long, showing that the cerebrum must be compressed from side to side, so as to taper anteriorly at a rapid rate. The floor of the brain-case is concave in length, but the concavity is divided into two principal portions—the posterior one corresponding to the basisphenoid region, and the anterior one, which is less regular, occupying the presphenoid region. The roof of the brain-case now has two bony processes extending into it; first, the small one, already described, which has not greatly altered its shape, though it is perhaps a little narrower and directed further downward and is more anterior in position. The portion of the brain or cerebral region anterior to this ridge, which is thus shown to extend transversely and obliquely forward and outward over the brain, is about 5 centimetres from the superior termination of the brain in front, as seen in the section; and different from the condition in the middle line, this upper surface of the cerebrum now appears in this lateral position to have been slightly concave in length. Its depth at the somewhat abrupt anterior termination is less than $2\frac{1}{2}$ centimetres; but the form of the section shows that the cerebrum was here slightly wider at the base than at its upper border. The depth of the cerebrum increases posteriorly to 3 centimetres, so that its upper surface must have been convex from side to side, since the depth decreases on passing out laterally from the middle line. At the position where the pineal gland should be, the cerebrum on this section has a depth of $3\frac{1}{4}$ centimetres. Behind its small limiting transverse ridge, already alluded to, is the deep excavation upward for the optic lobe (*o*). Its height from the base of the brain-case is, however, now reduced to 4 centimetres; its antero-posterior extent is less than 2 centimetres; it is margined posteriorly by a strong bony mass which separates it from the cerebellum. The cavity for the optic lobe is a little compressed superiorly and directed backward; but since it rises high above the cerebrum and occurs in the position where the brain-case becomes widest, the optic lobes may be inferred to be more developed laterally than in the median line, and probably extend outward laterally as far as the cerebrum. The bony mass, which at first sight resembles a tentorium, descends for more than 3 centimetres from the roof of the brain-case, so as to leave a channel less than a centimetre deep between this part of the brain-cavity and the floor of the brain-case. Its antero-posterior measurement is about $1\frac{1}{2}$ centimetre, though its outline is irregular and it is rather compressed inferiorly. As it does not extend transversely across the brain it is clearly a mass bulging inward from the side of the brain-case. Examined carefully it shows a long Y-shaped groove or canal which is occupied by matrix. The bones lying respectively in front of and behind the long stem of the Y are probably the prootic and opisthotic of Professor Huxley, while the bone above would be the epiotic. In some living Crocodiles these bones extend inward into the brain-case, though never to this great degree; nor have I observed any approximation to this character in the cranial cavities of other Teleosaurians; hence, as the surface of the bone is removed and the margins of the groove are sharp, the diverging branches of the Y (fig. 2, ?, ?′) may be anterior and posterior semicircular canals. The section of the cavity for the cerebellum is subquadrate, being flat above and below, with the sides nearly parallel. It is 2 centimetres deep, and about $2\frac{1}{4}$ centimetres long. The cerebellum obviously very narrow, though the transverse width of the foramen magnum, which was transversely ovate, was about 3 centimetres.

From this description it will be manifest that the brain of this Teleosaur differs remarkably from that of living Crocodiles in the compressed form of the optic lobes, in the cerebrum tapering anteriorly, and in the development of bony processes corresponding to the divisions between the chief elements of the brain. The existence of these processes may perhaps be taken as indicating that the brain filled the cerebral cavity; and therefore these animals present no analogy to Chelonians, which have the brain sheathed in cartilage. This condition of the cerebral region makes a marked difference from Plesiosaurs on the one hand and existing Crocodilia on the other, and supports the idea that the TELEOSAURIA constitute a reptile type in which the obvious resemblances to the living Crocodiles have been somewhat too emphatically insisted upon. It is instructive to compare this section with that of a skull of *Iguanodon* figured by Mr. Hulke, where the posterior region, presumably occupied by the cerebellum, is similarly depressed, and anterior to this the brain rises into a convexity for the posterior part of the cerebrum and optic lobes, only without any trace of a bony division between these two regions, such as is seen in this Teleosaur; and then the brain becomes depressed anteriorly much after the Teleosaurian pattern, only the cerebrum is relatively short in the Dinosaur, and the brain has its chief extension posterior to the pituitary fossa, which is the reverse of what obtains in the Teleosaurian.

The Gavial of Caen, named by Geoffroy *Teleosaurus cadomensis*, has been well figured by Cuvier in the seventh plate of the 'Ossemens Fossiles.' His fig. 1 represents a longitudinal section of the skull, which displays a side view of the cast of the cerebral cavity. The total length of the cerebral cavity is 6 centimetres. The specimen shows the cerebrum to consist of a posterior part with an ovate inflation and smooth lateral surface, which is 2 centimetres long; but it contracts and becomes depressed anteriorly, and extends forward for about another centimetre. This anterior portion of the brain, something like the olfactory lobes of a mammal or fish, extends under the frontal bone and in advance of its transverse expansions which form the front border of the large temporal fossæ. Posterior to the cerebrum the optic lobes are well defined; they are less wide than the cerebrum, with the sides flattened and depressed in the middle. The cerebellum is rather narrower than the optic lobes, and was evidently less high, with its lateral aspect more rounded. It is thus seen that the anterior part of the brain only occupies about half its length; and it is difficult to suppose that this length would be greatly augmented were the section made in the middle line of the skull. The optic lobes are far longer than in the Whitby fossil, indicating, I think, a different genus. There are indications of a bony ridge separating the optic lobes from the cerebellum, but no evidence that it descended between these parts of the brain like the otic bones in the specimen described.

It is impossible to state accurately the depth of bone which covers the brain in the Whitby fossil, because, as already mentioned, the median crest is partly broken away; but, as preserved, the depth at the posterior termination of the cerebrum is about $2\frac{1}{2}$ centimetres, while the thickness of the bone at the anterior termination is about

18 millimetres. Over the posterior part of the brain the thickness of the bone was more than doubled. The section shows the basioccipital to be large and strong, and very closely blended with the basisphenoid. There is no separate suture indicating the presphenoid. In the median line, and in the basisphenoid bone, below and somewhat behind the pituitary excavation, there is an inverted flask-shaped cavity 18 millimetres wide, which terminates downward in a tube nearly 1 centimetre wide, which is directed backward and imperfectly preserved, and appears almost to impinge upon the basioccipital bone. This tube (*Eu*) I regard as the Eustachian tube; and the ovate cavity with which it communicates (*TA*) I regard as being a portion of the tympanic air-cell, which would thus appear to have no bony separation dividing the portions on the two sides of the head. This tympanic air-cell on the right-hand section has become more irregular in shape, and is larger, being about 2½ centimetres deep and about a centimetre high, though a bony process indents the posterior margin considerably. The fractured condition of the external part of the right half of the brain-cavity shows another section of the tympanic air-cell, still irregular in form, but subquadrate and enlarging as it passes outward; while the vertical fracture parallel to the median line of the skull, seen on the outer part of the left side of the skull, shows this air-cavity, which has a thin border formed in front by the prootic bone of Huxley (alisphenoid bone of Owen), to be subovate, rather irregular in outline, about 4¾ centimetres long and 3½ centimetres deep, with a sharp plate of bone penetrating inward from the middle of its posterior side. Anterior to this cavity (which attains a development altogether unparalleled among the living Crocodilia), the left-hand side of the median section of the skull shows an ovate perforation 1½ centimetre in advance of it. This cavity is 2½ centimetres long and less than 1 deep; its border is somewhat irregular, and I regard it as a section of the carotid canal (*c c*). It lies just below and on one side of the position of the pituitary pit; and appears to be a canal which passes still further outward as it extends forward. The basioccipital has much the same form as in Plesiosaurs. The occipital condyle is rounded, 4½ centimetres deep and about 5½ wide; it has a central depression, and is margined by a sharp ridge where the external articular surface ends. This ridge increases in sharpness as it descends; and there is a deep excavation or constriction under its inferior border, so that from the neural canal to the base in front of the ridge the depth is 3½ centimetres; and here the excavation is concave. The bone extends downward and a little backward in the median line, on the side of which a nutritive foramen enters the bone. The texture of the bone is dense posteriorly towards the articular surface, and the cells are arranged longitudinally; but in the anterior part of the bone the cells become relatively very large. The length of the bone cannot be certainly stated, but appears to be about 5½ centimetres; its anterior border is convex from above downward. The basisphenoid (*Bs*) is densest

in its middle part. The anterior median process has large longitudinal cells; the posterior part has the cell-matter arranged vertically. The distance from the basioccipital margin to the median anterior process of the basisphenoid, where the excavation occurs which descends into the bone, is less than 5 centimetres; and the depth of this process, which is rounded in front, is 17 millimetres. The roof-bones of the skull are marked by the large longitudinal cells, except where the dense substance of the otic bones extends inward, and where the cells are directed obliquely downward and forward at the junction of the supraoccipital bone with the parietal.

The occipital aspect of the skull appears to have conformed to the usual Teleosaurian pattern, but is too imperfectly preserved for description. The exoccipital bones (*Eo*) entered into the upper and outer parts of the occipital condyle, and are divided from the basioccipital, on the articular surface, by a deep suture, which, after leaving that surface, becomes prolonged downward and outward after the manner of existing Crocodiles. The occipital region appears to have been nearly vertical. The exoccipital bones were laterally expanded, much as in living Crocodiles, but more prolonged outward, below the foramen magnum, descending to a level with the base of the occipital condyle. About $1\frac{1}{4}$ centimetre from the foramen magnum laterally is a round perforation for the vagus nerve (*Va*); and below this, and further outward, $3\frac{3}{4}$ centimetres from the foramen magnum, is a larger perforation like that in the Crocodile. The exoccipital is fractured vertically at about $6\frac{1}{2}$ centimetres from the middle line of the skull. I cannot say whether the opisthotic or paroccipital is distinct; if so, it is very large and makes the hinder wall of the great air-cell. The arrangement of the roof-bones of the skull conforms entirely to the usual Teleosaurian pattern.

The skull becomes greatly expanded transversely at its hinder part (fig. 4), chiefly owing to the excavation of the large tympanic air-chamber which penetrates the bones; and anteriorly the skull is constricted, so that its least measurement from side to side is about $6\frac{1}{2}$ centimetres at this distance from the anterior fracture. The skull then widens out again, so that at the anterior fracture its width must have been about 10 centimetres (fig. 4). Seen from the side, a rounded median ridge (fig. 3), which becomes sharpened in front and which is necessarily concave from front to back, divides the lateral region of the brain-case into superior and inferior aspects. The superior aspect slopes obliquely downward from the median longitudinal crest. Its upper part throughout the length of the specimen is occupied by the parietal bone (fig. 4, *P*). This is fully 4 centimetres deep in front, becomes reduced to less than half that depth in the middle (fig. 3, *P*), where the skull is most constricted from side to side, and again widens somewhat as it runs backward, and curves outward in a T-shape in the transverse line of the occipital crest. Its outward extension is a thin plate, resting upon a large expanded bone which forms the posterior half of the wall of the brain-case below the parietal. This bone forms the upper part of the wall of the tympanic cavity, but no satisfactory suture can be distinguished between it and the exoccipital bone. It is in the position of the prootic bone of the Crocodile, but is enormously developed so as to present the most distinctive feature of the cranial region of a Teleosaur. This bone, which is imperfectly preserved at its outer and posterior border, has a nearly vertical anterior suture less than 4 centimetres long, like that in living Crocodiles, a straight inferior suture, and a curved superior outline, determined by the overlap of the parietal bone. The bone is wider in front than behind: its greatest depth is $4\frac{1}{4}$ centimetres; its greatest length, as preserved, $7\frac{1}{4}$ centimetres; its surface is smooth and concave. Almost immediately below the anterior suture of this bone, at a distance of about a centimetre, and looking on to the under part of the skull, is a large transversely ovate perforation with rounded borders, 2 centimetres in length, into which it does not enter. This is, I presume, the outlet for the fifth nerve (fig. 3, *V*). It is placed just behind the pituitary body. If this perforation is rightly determined, and the nomenclature adopted by Professor Huxley is followed, the bone which lies in front of this perforation is the alisphenoid; and if the orbito-sphenoid has any separate existence, the condition of the specimen is such that it cannot be recognized. But if we were rather to name the bone alisphenoid which unites with the basisphenoid, following the nomenclature of Prof. Owen, then the orbito-sphenoid would form the anterior wall of the brain-case. The bone posterior to the nerve-outlets is certainly the quadrate, as in living Crocodiles. In perfect Teleosaur skulls it meets the squamosal above and the exoccipital behind; and it forms the anterior and inferior wall of the tympanic cavity. The anterior wall of the brain-case or alisphenoid (*als*) is imperfectly preserved anteriorly. It is a large oblong bone, concave and irregular on the underside, where the pterygoid lapped along its length, slightly concave in length above, and slightly convex from above downward. It appears to be about 6 centimetres deep, and the greater part of it lies above the longitudinal angular ridge running along it already alluded to. Owing to the form of the parietal it is much deeper behind than in front. The base of the skull is too much worn for useful description.

So far as I can judge by comparison with the type specimens in the British Museum, this species differs materially in the outer shape of the brain-case from the *Teleosaurus Chapmani*. The *Teleosaurus brevior* is too imperfectly preserved in this region for satisfactory comparison. I am not acquainted with any species from the Secondary rocks which closely resembles this species in the form of the prootic bone, or of the tympanic region, or the general shape of the brain-case. As its characters are likely to be of some interest, it may be useful to name the species for the present *Teleosaurus eucephalus*.

EXPLANATION OF PLATE XXIV.

Teleosaurus eucephalus.

Fig. 1. Left side of skull, nearly in median line.
2. Right side of skull, showing a section parallel to fig. 1.

These figures are of the natural size.

3. Lateral view of left side of same skull, greatly reduced.
4. Superior view, reduced.
5. Diagram of anterior end of fig. 1 (reversed).

In all the figures the lettering is the same:—*So*, supraoccipital; *Bo*, basioccipital; *Bs*, basisphenoid; *ps*, presphenoid; *Va*, vagus nerve; *FM*, foramen magnum; *Eo*, exoccipital; *P*, parietal; *Eu*, Eustachian tube; *TA*, tympanic air-cell; *V*, outlet for fifth nerve; *cc*, carotid canal; *als*, alisphenoid; *po*, prootic bone; *Q*, quadrate bone; C^m, cerebellum; *o*, optic lobes; *C*, cerebrum; *olf*, olfactory nerve; *op*, optic nerve; *pf*, pituitary fossa; ?, posterior semicircular canal; ?′, anterior semicircular canal.

Discussion.

Mr. Charlesworth mentioned that the Earl of Zetland had presented another interesting specimen of a Saurian to the York Museum, which was described by Prof. Phillips under the name of *Plesiosaurus Zetlandicus*; but M. Deslongchamps regards it as so peculiar in its characters as to entitle it to form the type of a new genus.

The President thought, with Mr. Charlesworth, that the specimen in the York Museum does not belong to the genus *Plesiosaurus*.

A S Foord del et lith. Mintern Bros imp.

TELEOSAURUS EUCEPHALUS.

Quart. Journ. Geol. Soc. Vol. XXXVI. Pl. XXV.

A. S. Foord del. et lith.

Mintern Bros. imp.

ICHTHYOSAURUS ZETLANDICUS.

45. *On the* Skull *of an* Ichthyosaurus *from the* Lias *of* Whitby, *apparently indicating a new Species* (I. Zetlandicus, *Seeley*), *preserved in the* Woodwardian Museum *of the* University of Cambridge. By Professor H. G. Seeley, F.R.S., F.G.S., &c. (Read June 23, 1880.)

[Plate XXV.]

Earl Zetland many years ago presented to the Woodwardian Museum a superb skull of *Ichthyosaurus*, which pertains to a new species, and from its value in exemplifying the osteology of the skull is in many respects the finest specimen known.

The anterior part of the snout is lost, but what remains of the head is 28 inches long. The snout has the aspect of having been at least 6 inches longer. Where fractured in front the jaw is 3 inches wide and 2½ inches deep. Its greatest transverse width behind the eyes and in front of the quadrate bones is 16¼ inches, so that it would appear to have been somewhat more than twice as long as wide. The occipital region unfortunately is badly preserved, and the basioccipital bone is a little displaced downward and forward. There is also some imperfection of the bones of the right orbit; but otherwise the skull is in excellent preservation. Being in a hard limestone it has escaped compression and distortion, and the limestone having been cleared with a chisel, the bones of the palate as well as those of the upper surface of the skull are beautifully displayed.

In transverse section behind, the outline is a trapezoid; the upper outline of the skull, being flat and horizontal, is 10 inches wide and parallel to the lower outline. The base, as already mentioned, is 16¼ inches wide. The oblique sides formed by the bones behind the orbits are 7½ inches from the base of the quadrato-jugal to the junction of the squamosal with the postfrontal. From the middle of the orbit backward the lateral outline is convex, and though the margin of the orbit is nearly straight the lateral outline anterior to it is gently concave. The flattening of the skull on its upper part covers a triangular space defined by rounded angular ridges crossing the nasal bones, and converging forward to disappear in their anterior third. These ridges, prolonged backward, cross the postfrontal and become prolonged round the outer and upper border of the temporal fossæ. External to this space, which is depressed and concave in the region of the nasal and frontal bones, are the sloping sides of the skull, which converge upward, and in the anterior part of the snout, formed by the premaxillary and nasal bones, round together into a somewhat semicylindrical form. Posterior to the orbit there is a convergence of the lateral areas towards the occipital region. This broad flattened form of a skull with oblique orbits looking upward and outward is so different from all European species hitherto figured that I venture to describe it, although there may be some difficulty hereafter in determining the vertebral column with which it was originally associated.

First it may be convenient to consider the upper surface of the skull (Pl. XXV. fig. 1). The *temporal fossæ* (*TF*) are large, ovate, and narrower behind than in front, and have their posterior ends directed a little outward and backward. Their length is about $6\frac{3}{8}$ inches, and width about $3\frac{3}{8}$ inches. Their inner border is formed by the parietal bones, the posterior border and posterior half of the lateral border by the squamosal bone, and anterior border and anterior half of the lateral border by the postfrontal bones. But on the inner side of the outer bar above the eye is a plate of bone lapping along the inner sides of the squamosal and postfrontal. The state of the specimen does not demonstrate conclusively whether it is to be referred to the squamosal or other postorbital element or to a separate bone not hitherto recorded in the Ichthyosaurian skull. This outer margin of the temporal fossa is comparatively straight; the inner border is much more curved. The outer bar, formed by the squamosal and postfrontal bones, is thin, and on the whole suggests the same region in the skull of *Hatteria*, though the squamosal bone extends further forward on the outer side than in that living type. The extreme width of the temporal fossæ from one temporal bar to the other is 10 inches measured from the inner side, and about 11 inches measured from the outer side.

The *supraoccipital* bone is absent from the skull; but since the parietal terminates posteriorly in a suture in the shape of a broad W with the median process less developed than the lateral wings, which are prolonged outward and backward to meet the squamosal bone, it is probable that it was fairly well developed, and gave to the back of the skull a transversely concave, but more than usually straight transverse outline. The *parietal bones* (*p*) are divided in the middle line by a suture and are deeply grooved in the anterior part by the fissure which terminates anteriorly in the parietal foramen (*FP*), though this foramen is not more than $1\frac{1}{3}$ inch wide, and the groove is not more than $2\frac{1}{2}$ inches long, so that it is relatively much less developed than in the Ichthyosaurs from the Lower Oolites. The extreme length of the parietals is about $6\frac{1}{2}$ inches; but in front of the foramen the bones divide, and receive the narrow frontal bones (*f*) between them for a length of about $2\frac{1}{5}$ inches. The anterior divergences terminate in sharp-pointed processes which are about $1\frac{7}{10}$ inch apart. The parietal has its lateral surfaces, which form the outer wall of the brain-case, smooth, concave in length, and gently convex from above downward, so that the convex surfaces form a slight median ridge above, except that the bone becomes a little flattened laterally in front on each side of the parietal groove. The least width of the bones in the middle of the brain-case is $2\frac{4}{5}$ inches. They widen posteriorly in a curve to $4\frac{1}{4}$ inches. They also widen anteriorly and send similar anterior processes along the anterior border of the postfrontal, and there the transverse expansion is somewhat greater. These anterior lateral outlines of the parietal bones are separated from the anterior forked terminations by the intervening inner part of the postfrontal bone (*pt*), which juts in almost at a right angle. The anterior terminal processes referred to divide the postfrontal bones entirely, or almost entirely, from the frontals, and themselves unite with the nasal bone (*n*). The temporal fossæ (*TF*) have not been sufficiently excavated to show the depth of the parietals or their relations to the lower bones of the brain-case. In front of the parietal are the *frontal bones* (*f*), rather narrower than usual, and having a length of $4\frac{1}{4}$ inches. They are less than $\frac{9}{10}$ of an inch wide posteriorly, where they are truncated by the parietal foramen. They are widest at the anterior termination of the parietal bones (*p*); and posterior to this their converging lateral outlines, though somewhat irregular, are gently concave. The anterior lateral outlines are less than twice as long as the posterior part, are straight, and converge to a point, so as to give the bones somewhat the outline of a spear-head. They are each a little convex from side to side, and are divided by a median suture, which is most impressed in front. The posterior parts of the bones articulate exclusively with the parietals, the anterior part exclusively with the nasal bones, which they gently separate posteriorly.

The *nasal bones* (*n*) are, as usual, the great roof-bones of the fore part of the head. Their anterior termination is not distinctly seen; for the upper surface has suffered an injury by which their extremities have been removed. Measuring from the angle between the parietal and postfrontal bones to the apparent anterior extremity, beyond the visible termination of the nasals, the distance is about 17 inches. As already remarked, the nasals are angularly bent, so that the upper portions form the roof of the skull, and outer oblique parts form the upper border of the side of the skull in front of the eye and above the nares. The posterior half of the upper surface is concave from side to side, having a width in the hinder region of about 4 inches. The outline of the nasal bones is necessarily a long spear-shaped triangle, tapering in front and wide behind. They form in the middle of their own external borders part of the upper wall of the anterior nares, but are not indented by them; they expand a little by descending on the lachrymal bones (*l*) to form the upper margin of the posterior border of the narial cavities. They then have a sinuous union, at first concave and then convex, with the superior borders of the large lachrymal bones, and behind these pass interior to the small prefrontal bones on to the postfrontal. Each bone divides posteriorly into two forks: the inner wedge-shaped pair have their sides converging to blunt points separated by an interspace of $4\frac{7}{10}$ inches; they join the frontal, parietal, and postfrontal bones. These inner processes are divided from the outer pair, which are directed outward and backward, though not quite so far as the others, by a triangular forward wedge of the postfrontal bone extending between them; and this outer process of the nasal, which is only preserved on the left side, has its margins nearly parallel, and terminates in three claw-like digitations. It prolongs backward the line of the rounded angular ridge running along the nasal bone. These ridges are marked with a few longitudinal parallel grooves, which, however, cross them at a slight angle, being prolonged a little further forward, and down into the boat-shaped depression in the head formed posteriorly by the nasal, frontal, and postfrontal bones. Anterior to these rounded ridges the bones are somewhat flattened above, but rounded from side to side. The median suture dividing them is about 13 inches long. The width of the nasal bones measured transversely between the nares is $3\frac{1}{2}$ inches; the transverse width of the skull in the line of their posterior borders is about $8\frac{1}{2}$ inches, while the transverse width of the skull at their anterior termination is about $4\frac{1}{2}$ inches.

The *premaxillary bones* (*pm*), as already remarked, are imperfect anteriorly; they are preserved for a length of over 11 inches, but the part where they meet superiorly in the middle line, undivided by the nasal bones, is only about 3 inches long. The sides are a little flattened, but they round convexly above, and the median suture is a little impressed, so that the limits of the bones are distinctly marked by a groove, unlike the anterior portion of the nasal bones. As the premaxillary bones extend backward they narrow a little from being overlapped on the alveolar border by the maxillary bones (*m*); their upper and under sutures are comparatively straight and subparallel. Each bone is forked at its posterior termination by receiving in a notch the anterior part of the long ovate anterior nasal aperture. It forms more than a third of the wall of this cavity on the right side, and on the left side is prolonged along nearly the whole upper margin, so as almost to exclude the nasal bone from the anterior nares. The lateral surface of the premaxillary is somewhat roughened with vascular perforations in its hinder part. The only other bones which enter into the upper surface of the skull are the postfrontal and squamosal, which may be more conveniently described in noticing its lateral characters (fig. 2).

The anterior nares (*N*) vary a little in their distances from the back of the head; measuring from the hinder border of the squamosal bone to the posterior border of the nasal aperture, the distance is about $14\frac{1}{4}$ inches. The length of the nostril is $4\frac{1}{2}$ inches, and its depth in the posterior third $1\frac{3}{4}$ inch. Its distance from the end of the snout, as preserved, is rather less than 9 inches. The posterior border of the cavity is rounded and formed by the nasal bone above and the lachrymal bone behind and below. The middle of the base, which is straighter than the upper border, is formed by the maxillary bone; and anteriorly the nostril terminates, as already indicated, in the premaxillary in a sharp angular notch.

The *maxillary bone* (*m*) is much longer on the left side of the head than on the right side, though the alveolar border is better preserved on the right side. Its length on the left side is about twelve inches; on the other side it is much less. I am not sure from the condition of the palate how many teeth it contains; but as it extends forward almost to within 5 inches of the truncated end of the snout, I have no doubt that it contained several, since the alveoli extend along fully $8\frac{1}{2}$ inches of the palatal border as preserved.

The bone, as usual, is slender on the lateral alveolar border in front and slender behind. It extends below the lachrymal bone, and joins the malar at about the anterior border of the orbit; and thus excludes the lachrymal bone from the base of the skull. The *lachrymal bones* (*l*) extend between the orbits and nares; they are broad hatchet-shaped bones. The inferior border is convex, and the superior border sinuous. The posterior border is concave, and the bone has a spine-like prolongation extending along the anterior part of the base of the orbit. Its least antero-posterior length between the two lateral cavities into which it enters is $2\frac{3}{4}$ inches, while its depth is $4\frac{1}{2}$ inches. It unites above with the nasal bone (*n*) in front and the prefrontal bone (*pf*), and below with the malar bone (*ma*) behind and the maxillary (*m*) in front. The surface of the lachrymal bone below the nasal is somewhat impressed, as though its surface might have lodged a gland; and its margin, which enters into the orbit, is rounded, thickened, elevated, and continuous with that of the prefrontal bone above and the malar bone behind. The large size of the lachrymal bone and its great antero-posterior extent between the orbit and narine make one of the most distinctive characters of the species.

The *orbit* (*O*) is large and oval, much less vertical than usual, since the transverse measurement between the base of the orbits behind is somewhat less than 14 inches, while the measurement between the superior borders in front is about $7\frac{3}{4}$ inches. Lines drawn through the middle of the orbits horizontally would converge some distance behind the anterior termination of the nasal bones. The length of the orbit is 8 inches, its depth $6\frac{1}{4}$ inches. It forms almost the entire height of the skull, which in this position, measured vertically, is less than 7 inches. Its border is rounded from within outward, and the outline of the cavity is regular. It is margined superiorly by the prefrontal and postfrontal bones; the middle of the base is formed of the malar bone, which is encroached upon anteriorly by the lachrymal bone, which forms its anterior end, and posteriorly the postorbital bone forms its posterior end.

The *malar bone* (*ma*) is a slender bar, rounded above, and somewhat flattened on the underside in front, but more compressed and rounded behind. Its length is about $8\frac{1}{4}$ inches. It is comparatively straight, though slightly curved in length and convex on the outer side. Its anterior end tapers, and underlaps the lachrymal bone. Its posterior third receives the postorbital bone above (*po*), and its posterior extremity is more compressed from below upward for a length of an inch and a quarter, and is received between the postorbital and quadrato-jugal bones (*qj*).

The *postorbital bone* (*po*) is somewhat broader than usual, and hence has not quite so much of a crescent shape, its outline being more that of a boot, the anterior concavity forming the orbital border. The length of the base which rests on the malar is about $3\frac{1}{2}$ inches, while the width of the bone in its upper part is less than half as much. The base is comparatively straight, as is the posterior border, which joins the quadrato-jugal bone (*qj*), and in its upper part meets the supraquadrate (*sq*). The upper border of the postorbital unites by transverse slightly irregular suture with the postfrontal bone.

The *prefrontal bone* (*pf*) is relatively small as compared with that of some other species. It is an irregularly oblong bone, somewhat compressed behind, with its orbital border necessarily concave, joining the lachrymal in front by a nearly vertical, but slightly oblique suture. It joins the nasal by a straight suture above in its front part, and the postfrontal behind and above by an oblique irregular suture. Its length is about 3 inches, and its depth in front, where greatest, is about $2\frac{1}{4}$ inches.

The *postfrontal bone* (*pt*) is broad transversely on the roof of the skull, and becomes compressed from side to side in its posterior part, which is bent backward at a considerable angle to form the upper border of the orbit (fig. 1). The outline of this bone is concave posteriorly where it enters into the temporal foss, as well as inferiorly where it enters into the orbit (fig. 2). Its superior surface is flattened and elevated in front of the temporal foss; but anterior to this elevated transverse ridge, which becomes narrower as it extends outward from the parietal bone, the bone is depressed anteriorly towards its union with the inner part of the nasal. Its inner truncated end is received between divergent processes of the parietal bone; and owing to the middle of its anterior part being overlapped, as already remarked, by a claw-like posterior process from the nasal bone, it is divided into two angular portions. The inner of these extends forward in a V shape into a corresponding notch in the nasal bone; and the outer extends rather further forward in a more irregular way between this claw-like process of the nasal and the compressed posterior part of the prefrontal bone. The extreme length of the bone appears to be about 8 inches; its extreme transverse width is under 5 inches; but the outer part of the bone being bent so as to descend at the back of the orbit, the measurement taken in the two planes is greater. The extreme extension forward of the bone from the interior margin of the temporal foss is less than $3\frac{1}{2}$ inches, and its anterior width is somewhat greater. Its posterior end joins the squamosal bone at about the hinder third of the outer margin of the temporal foss, while its inferior border rests upon the postorbital bone in front and the supraquadrate bone behind.

The region of the skull which is posterior to the orbit and below the temporal foss is flattened, comparatively smooth, and obliquely inclined, so that it looks outward and upward. It is convex in length, rounding towards the posterior end of the skull, and is slightly concave from above downward. It is formed by the squamosal and postfrontal bones above, below which are the postorbital and supraquadrate bones, with the triangular mass of the quadrato-jugal forming the base and posterior prolongation of the alveolar border, and dividing the lower parts of these bones from each other by extending upward between them.

The *squamosal bone* (*sqm*) is a curved sickle-shaped element, which joins the outer posterior angle of the parietal bone somewhat low down by a strong thickened mass, which is prolonged outward and a little backward. It curves and becomes bent round in front and is directed forward and greatly compressed from side to side, so as to form the outer posterior border of the temporal foss, where it is 2 inches deep. It is apparently prolonged forward under the postfrontal bone along the length of the temporal foss, though, as already remarked, some doubt may attach to the identification of the bony element which extends behind and below the posterior branch of the post-frontal bone. If it should not be formed by the squamosal it is probably formed by the postorbital, extending upward and expanding so as to bind together the other bones posterior to the orbit.

The *supraquadrate bone* (*sq*) has also been called by Prof. Owen the supratemporal and suprasquamosal. It, like the postorbital, is unossified in the Crocodile, in which type the skin extends over the same areas as are here covered by these bones. This supraquadrate I so name because, extending between the squamosal bone above and the quadrato-jugal bone below, it rests upon and hides the quadrate bone in the lateral aspect of the skull. It is subtri-angular in shape, having a vertical measurement of $3\frac{3}{4}$ inches, and an antero-posterior measurement of about $4\frac{1}{2}$ inches. Its posterior border is obscured by matrix; its superior border is comparatively straight, while the oblique inferior border which abuts against the quadrato-jugal is sinuous, the basal angle being broad. Finally, there remains the *quadrato-jugal bone* (*qj*), which has the oblique position of the other bones described and a somewhat triangular outline. Laterally its base is convex from front to back and comparatively straight in length. It is, as indicated, wedged between the supraquadrate and the postorbital bones, which indent its borders somewhat concavely but irregularly. Its height is $5\frac{1}{2}$ inches and the length of its base is over 4 inches. Behind and below the quadrato-jugal, but entirely anterior in position to it, the articular end of the massive quadrate bone (*q*) descends and receives a process from the pterygoid bone on its inner side.

Palatal aspect of the Skull.—The hard limestone forming the matrix of this specimen has been carefully chiselled away so as to display the bones of the palate (fig. 3). These elements are beautifully distinct in the posterior part of the skull, but anteriorly there has been some little difficulty in making clear the relations of the bones. It follows from the description given that the premaxillary bones (*pm*) are prolonged outward and backward by the slender bar of the maxillary (*m*), which is continued by the malar (*ma*) and quadrato-jugal (*qj*) to the quadrate (*q*). This bar becomes somewhat thinner posteriorly, but defines the lateral outlines of the back of the head on its palatal aspect. There are on the palate apparently three pairs of vacuities:—first, a small anterior pair (*V*) lying below the exterior nares and between the outer bones of the palate; secondly, a posterior median pair (*SP*) divided by the presphenoid bone and lying between the pterygoids; and, thirdly, a pair of irregular lateral spaces (*PTV*) between the pterygoids and the malar arch, which extend back to the quadrate bone and are prolonged forward for an uncertain distance, but apparently at least as far as the region of the exterior nares. In the median line of the base of the skull are seen the displaced basioccipital (*bo*), the basisphenoid (*bs*), and presphenoid (*ps*), the latter two being anchylosed together. The *basioccipital* has a somewhat flattened hemispherical articular surface, rough with concentric markings of attachment, and defined, as usual, by a moderately deep vertical and inferior groove. It is about 3 inches wide. Below and in front of this part of the bone is a smooth non-articular surface, which is concave in the middle and, where widest, extends the width of the bone to nearly 4 inches. Its length is rather over 3 inches, and, as is usually the case with Liassic Ichthyosaurs, it has the anterior margin, where it abuts against the basisphenoid, convex from side to side. The *basisphenoid bone* (*bs*) is exposed but little. It appears to have been about 2½ inches long, with a strong elevated ridge in the middle of the base, on each side of which the surface is concave. This ridge is prolonged forward into the sword-shaped presphenoid bone (*ps*) with which it is anchylosed. On each side of the presphenoid the anterior margin of the basisphenoid is deeply concave; the posterior lateral portions of the basisphenoid are overlapped by wide inward expansions of the pterygoid bones. The *presphenoid* slightly tapers as it extends forward, is compressed from side to side, preserves its inferior keel, and is at last received between a pair of bones anterior and interior in position to the pterygoids. It has a length anterior to the basisphenoid of about 8¾ inches.

External to these median bones there appear to be four pairs of lateral bones. The largest of these are the *pterygoid bones* (*p*), situate behind; the bones external to the pterygoids are two pairs—a slender anterior pair, which I regard as the *palatines* (*pn*); and a larger pair external to the palatines and extending partly along them and the pterygoids, but well separated from the malar, which I regard as the *transverse bones* (*t*); while interior to the pterygoids and the palatines and abutting against the presphenoid is another pair of slender bones which, from their position, I regard as the *vomers* (*v*).

The arrangement of the bones in this genus is very different from that in the genus in the Inferior Oolite of Caen, as shown by a skull in the British Museum, unless the bones which here have every appearance of separate existence, and which I regard as the vomers, should be an accidental condition marking a generic difference. Moreover the pterygoid in the Caen fossil, on the left side, consists of two separate osseous elements. The *pterygoid bones* (*p*) have their inner margins concave. They do not appear to have met posteriorly in the median line, though from the displacement of the basioccipital this cannot be stated with absolute confidence. They partly enclose the long pterygoid vacuities already alluded to, which are divided by the presphenoid. These vacuities are margined in front by the bones interior to the pterygoid which I have regarded as vomerine. The pterygoids are deeply notched out on the posterior aspect by a concave border, and in the external posterior half have a concave outline. Between these two concavities is a posterior compressed mass from which a process extends, at first outward and then backward and somewhat downward, lapping along the inner side of the quadrate bone. The external lateral concavities narrow the width of the pterygoid bones, and where they terminate anteriorly the bones widen again, but begin to converge forward and inward, terminating in sharp points. Their surfaces are smooth, and slightly convex from side to side in front. They descend a little downward as they extend outward, and are moderately thick bones. The length from the process meeting the quadrate to the anterior termination is about 13 inches on the right side, but apparently rather more on the left side. The least width from side to side between the external concave lateral margins in the hinder part of the bone is about $5\frac{1}{2}$ inches. The greatest width between the quadrate bones is nearly 10 inches. The width at the angle where the lateral concavity terminates in front is, across the bones and their interspace, less than $7\frac{1}{2}$ inches. The least width of each bone in its posterior constriction is rather over an inch and a quarter. Its width at the expansion in front of the constriction is over two inches. The distance from the posterior quadrate process to the anterior termination of the lateral concavity does not exceed $7\frac{1}{2}$ inches.

Lying within the pterygoid bones, and joining them by sutures nearly parallel to each other, are two bones which are to be regarded as *vomers* (*v*). They prolong the tapering outlines of the pterygoid bones inward, forward, and upward into the palate. They are divided from each other by the presphenoid bone. That on the left side extends somewhat further back than the bone on the right side. The least distance from the hindermost termination of the bone on the left side to the occipital condyle is about 10 inches, but about $4\frac{3}{4}$ inches further forward the condition of the specimen becomes a little obscure owing to a fracture here: there appear to be on each side of the presphenoid two small palatal vacuities, that on the right side being the larger and a little over an inch long. It is uncertain therefore whether these bones terminate at this point. If so, they can only be an anterior dismemberment of the pterygoids, and probably a distinct generic character in this Ichthyosaurian type. But in front of these perforations median palatal bones of corresponding width are prolonged forward in continuation of them, and without any appearance of break: and as I have found the vomerine bones lying on the sides of the anterior termination of the presphenoid in some transverse sections of small Ichthyosaurian skulls from the Lias, I am inclined to believe that the parts posterior to the perforations, as well as the long anterior bar or bars, are vomers. The vomers would appear to reach forward, in front of the small perforations referred to, to the extremity of the palate as preserved; but the condition of the palate does not demonstrate in this species whether the forward and narrow prolongation consists of two distinct bones; but on the polished end of the broken snout the two bones are visible in front (fig. 4).

External to the pterygoid bones, and equally prolonging the lateral contour, is another pair of slender bones which do not reach quite so far back as the vomer-like elements, though they are rather more symmetrical. These bones I regard as *palatine* (*pn*). They form the outer wall of the minute palatal narine-like perforations already referred to, and the inner wall of a larger pair of palatal vacuities which are placed immediately below the external nares and are bounded externally by the transverse bones. These palatine bones diverge posteriorly, and run as narrow bars along the outer borders of the vomerine bones. Their termination forward, from the condition of the palate, is not quite clear, though they appear to extend forward as far as the palate is preserved, and abut against the inner alveolar margin; but this is somewhat uncertain. The bones appear to widen a little in front of the palato-transverse foramina, and their least length is probably 12 inches. The width of the palate at the posterior termination is nearly 4½ inches. The vacuities which lie between the palatine and transverse bones are chiefly notched out in the lattter. They are relatively narrow, rounded posteriorly, wider behind than in front, and have a length of a little over 3 inches. The distance of the posterior border from the occipital condyle is about half the length of the skull. The width of the palate over these vacuities at their thin hinder borders is something over 4 inches. They converge towards each other anteriorly in conformity with the tapering of the skull forward. The *transverse bones* (*t*) are second in size to the pterygoids, and altogether larger than the palatine bones or the vomers. Owing to the condition of the skull, there is the same difficulty in fixing the anterior limit of these bones as there was with those last mentioned; but I am led, from the indications preserved, to conclude that both terminate forward at the anterior third of the specimen. If so, the transverse bones diverge backward in a long V-shape, and have a length of about 17 inches. Throughout the whole of the anterior ends they rest against the palatine bones, are prolonged as an outer border to the palatal vacuities, and then widen inward so as again to run along the palatines again till they terminate. They extend backward along the outer diverging margin of the pterygoids, gradually contracting in width and extending beyond the outer angle of the pterygoid into the pterygo-malar vacuity for over an inch. The posterior part of the bone has its external outline gently convex in length, and the widest part of the bone is at the point where the palatine terminates posteriorly, where it measures about 1½ inch from side to side. Its surface is smooth, convex from within outward, and it is placed obliquely, so that its outer border descends almost to the level of the malar and maxillary bones. There appears to be a long narrow vacuity between the maxillary and malar bones and the transverse; but it is impossible to say how far this might be modified in character if the specimen were entirely free from matrix, since the transverse bones are obviously thick, and may extend under the orbit. But for the slight posterior projecting processes of the transverse bones the cavity between the emarginate border of the pterygoid and the malar and quadrato-jugal, in which the lateral vacuities terminate, would be subovoid. Where widest the transverse measurement of each of these spaces is upwards of 4 inches.

There now only remain on the palate the articular ends of the large *quadrate bones* (*q*). These extend below the level of the palate and are subreniform, concave on the inner border where the pterygoid abuts, convex on the outer border, and narrower in front than behind. The articular surfaces are arranged longitudinally, and are more than twice as long as wide, convex in length as well as from side to side. That on the left side is a good deal broken away. The length of the articular surface is about 3½ inches, while its width did not exceed 1¼ inch.

I have already compared the skull of *Ichthyosaurus* with that of other extinct and living animals, in a paper published by the Linnean Society in February 1876 (Journal, vol. xii. p. 296), and only here would draw attention to the view enunciated by Professor Owen in the report of his lecture at the School of Mines in 1858 (Ann. Nat. Hist. ser. 3, vol. i. p. 395), that a truer conception of the affinities of the *Ichthyosaurus* may be obtained by comparison with Labyrinthodonts and other Triassic reptiles than with modern Lacertians and Crocodilians, for the sake of showing that the Crocodilian characters of the skull have been somewhat underestimated. In the memoir referred to I merely stated facts and possible interpretations. Now it seems to me that we are justified in going a step further, and by comparison with the Teleosaurs may gain some better insight into the relation of Ichthyosaurs with Crocodiles than would be furnished merely by evidence from the existence of bony elements like the supraquadrate bone only elsewhere found among Labyrinthodonts. For in the Teleosaurian genera we see the palate in process of being closed in the median line, though it is still open; and if the maxillary bones of *Ichthyosaurus* were supposed to develop larger palatine plates, so as to close the palate in the median line, then the palatine bones would come together as in the Crocodiles, and the pterygoid bones would be overlapped by them in part according to the Crocodilian pattern. If the median vacuities in the Ichthyosaurian skull were closed by the pterygoids meeting, then the vacuities between the transverse and palatine bones would remain homologous with the large palatal vacuities of Crocodiles, and the cavity behind the transverse bone in Crocodiles would correspond to the similar cavity in *Ichthyosaurus*. The Ichthyosaurian palate therefore seems to me to represent the Crocodilian palate before it has made any approximation to the median closing of the bones, which is one of the characteristics of the existing order.

With regard to the upper surface of the skull, both postorbital and supraquadrate bones are clearly unossified in the recent type; but the vacuities exist in Crocodiles in which they should be developed. The most striking differences of the hinder part of the skull in the two orders are chiefly matters of proportion, consequent upon the reduced size of the orbits in Crocodiles and their consequent loss of a more or less vertical position. But in fossil Crocodiles and Teleosaurs the temporal fossæ are relatively larger than in the living form; and in these animals we find a small prelachrymal vacuity which occupies the position of the external nasal openings in *Ich-*

thyosaurus. But if the nasal bones had not been prolonged in front of the nares, and the premaxillary bones had remained merely bounding their anterior margin, the resemblance of plan between the Crocodile and Ichthyosaur would have been more striking. However, though the long prenarial snout of *Ichthyosaurus* constitutes an excellent ordinal character, because it is constant, it does not appear, from an anatomical point of view, to be of much importance as a measure of an animal's affinities, because it depends on the development of the premaxillary at the expense of the maxillary bone. Important as are the differences of detail, there is a closer family relationship between *Ichthyosaurus* and living Crocodiles than between *Ichthyosaurus* and any other existing order of reptiles; and this resemblance in the skull is also faintly indicated in the vertebral column by the double-headed articulation for the ribs, which is not met with among true reptiles, and is more important as a mark of affinity than the development or absence of transverse processes when taken in connexion with skull-characters.

The only species to which the fossil described makes a near approach in proportionate width of the head is a large form from the Lias of Whitby, which Professor Owen had distinguished under the MS. name *Ichthyosaurus crassimanus*, and which the Rev. J. F. Blake, F.G.S., has briefly noticed in the 'Yorkshire Lias,' p. 253. Mr. Blake gives the head as 6 feet 3 inches long, and 3 feet wide behind, but without further description. So far as I remember, the skull in that specimen is greatly crushed, and its characters are obscured, so that a detailed comparison cannot well be made; but the impression left on my mind by studies made 16 years ago was to the effect that the large animal at York was distinct from the smaller species now described. I am acquainted with no other Ichthyosaur in which the skull attains this broad, triangular form, with the orbits so far apart from each other and so moderately inclined, and with the nares so far in front of the orbits and relatively so large. The bones posterior to the orbit are also more than usually broad. The quadrate bone too descends a good deal below its ordinary position. These characters sufficiently distinguish the species described from all others.

I would express my grateful thanks to Professor Hughes for his kindness in allowing me to describe and figure this specimen.

EXPLANATION OF PLATE XXV.

Ichthyosaurus Zetlandicus.

Figs. 1–3 are rather less than one fourth natural size.
Fig. 4 is reduced one half.

Fig. 1. The skull viewed from above. The premaxillary bones are imperfect in front.
2. The same skull seen from the side, showing the elevated head and large orbit.
3. Palatal aspect of the same skull.

Fig. 4. Outline of polished anterior end of the section of the jaws, showing teeth in the premaxillary bones, and the vomerine bones shaded occupying the median line of the palate.

In all the figures the lettering is the same:—

TF. Temporal fossa.
FP. Foramen parietale.
O. Orbit.
N. Anterior nares.
pm. Premaxillary bone.
m. Maxillary bone.
n. Nasal bone.
l. Lachrymal bone.
ma. Malar bone.
pf. Prefrontal bone.
f. Frontal bone.
pt. Postfrontal bone.
p. Parietal bone.
sqm. Squamosal bone.
sq. Supraquadrate bone.
qj. Quadrato-jugal bone.
po. Postorbital bone.
q. Quadrate bone.
bo. Basioccipital bone.
bs. Basisphenoid bone.
ps. Presphenoid bone.
p. Pterygoid bone.
pn. Palatine bone.
t. Transverse bone.
v. Vomer.
SP. Sphenoido-pterygoid vacuities.
PTV. Vacuity between the transverse and palatine bones.
V. Vacuity in the position usually occupied by the posterior nares.
x. Matrix.

46. *The* Glaciation *of the* Orkney Islands. By B. N. Peach, Esq., F.G.S., of the Geological Survey of Scotland, and John Horne, Esq., F.G.S., of the Geological Survey of Scotland. (Read June 23, 1880.)

[Plates XXVI. & XXVII.]

Contents.

I. Introduction.

In a former paper which we communicated to the Society on "The Glaciation of the Shetland Isles," we endeavoured to show how the evidence supplied by the striated surfaces, the *roches moutonnées*, and the dispersal of the stones in the Boulder-clay points to the conclusion that Shetland had been glaciated by Scandinavian ice. It was further argued that during the climax of glacial cold the Scandinavian and Scotch ice-sheets coalesced on the floor of the North Sea, and that the great outlet for the combined ice-sheets was towards the north-west by the Pentland Firth and the Orkney Islands.

In the course of the autumn of 1879 we visited nearly all the Orkney Islands for the purpose of continuing our researches with reference to the extension of the ice in the North Sea in the Glacial period. In the paper now presented to the Society we purpose to give a summary of the results of our observations. At the outset we may state that they furnish a remarkable confirmation of the conclusions already arrived at regarding the westerly and north-westerly movement of the ice. Moreover, the presence of stones in the Boulder-clay, which must have been derived from the mainland of Scotland, and the discovery of abundant remains of marine shells in the same deposit, though in a fragmentary state, are of the utmost importance in guiding us to a satisfactory solution of the question.

No description of the glacial phenomena of Orkney has hitherto been published *. Some references were made by Professer Geikie to

* Since this paper was written, our friend Mr. Amund Helland has sent us a copy of his paper "Ueber die Vergletscherung der Färoër Inseln," which appeared in the 'Zeitschrift der deutschen geologischen Gesellschaft,' 1879. We are glad to see that Mr. Helland has arrived at the same conclusions as ourselves regarding the north-westerly movement of the ice in Orkney, from independent observations made in the course of last year.

the existence of *roches moutonnées* with striated surfaces, Boulder-clay, and valley moraines in the islands in an article which appeared in 'Nature'*. This article was written in reply to a letter by Samuel Laing, Esq., M.P., in which he asserted that there is no evidence that Orkney had participated in the general glaciation of Britain †. So far from there being any lack of evidence regarding the glaciation of these islands, we hope to show that they contain abundant proofs of having undergone severe glacial conditions. Our observations, however, completely confirm Mr. Laing's statement that there are no raised beaches in the islands indicating changes of the relative levels of sea and land since glacial times.

II. Geological Structure.

The geological structure of the islands is comparatively simple. From Stromness on the Mainland northwards to Inganess there is an axis of ancient crystalline rocks on which the representatives of the Old Red Sandstone rest unconformably. These crystalline rocks consist of a fine-grained granite and a grey micaceous flaggy gneiss, which occupy a strip of ground about four miles in length and about a mile in breadth. They are prolonged southwards in the island of Graemsa. With this exception the whole of the Orkney Islands are occupied by Old Red Sandstone strata. In the island of Hoy representatives of both the upper and lower divisions of this formation are met with, and here they are separated by a marked unconformity; but in all the other islands the beds belong to the lower division.

Throughout the islands there is a remarkable uniformity in the character of the strata belonging to the lower division. They consist mainly of hard blue and grey calcareous flagstones, which are so typically developed in Caithness. Fortunately, however, the highest beds of the Orcadian flagstone series are totally different in character from those just described, being composed of coarse siliceous red and yellow sandstones and marls. The sandstones are full of false-bedding, and frequently conglomeratic, containing pebbles of granite, quartzite, gneiss, and other crystalline rocks.

The distribution of this arenaceous series has an important bearing on the question of the ice movement. On referring to the map accompanying this paper (Pl. XXVI.), it will be seen that it forms a well-marked zone, running nearly north and south through the centre of the group. The relations which these siliceous sandstones bear to the flagstones are best seen in Eda, where they cover the greater part of the island, and where they form smooth flowing hills upwards of 300 feet in height. The sandstones lie in a syncline, the axis of which runs north and south, and on both sides of the island they rest conformably on the flagstones. In the islands which lie to the west and north-west of Eda, viz. Fara, Westra, Papa Westra, Egilsha, and Rowsa, the strata consist wholly of blue and grey flagstones, which are inclined at gentle angles. Though there are

* 'Nature,' vol. xvi. p. 414. † 'Nature,' vol. xvi. p. 418.

many minor undulations, yet on the whole there is a gradually descending series towards the western headlands of Rowsa and Westra.

In Stronsa and Sanda the arenaceous series and the underlying flagstones are repeated by a series of faults, which are laid down on the map.

The south-east corner of Shapinshay is occupied by these sandstones, where they are associated with a dark green slaggy diabase, which forms part of an ancient lava-flow. They reappear on the south shore of Shapinshay Sound, and cross the Mainland in a narrow strip from Inganess Head to Scapa Bay. They are continued also along the north-west shore of Scapa Flow as far as Orphir Kirk, and they likewise extend along the eastern shore to Howquoy Head, near St. Mary's. These sandstones and marls are brought into conjunction with the flagstones of the Mainland by two great faults, which we have traced on the ground; but in Cava, Fara, Flota, South Ronaldshay, and Burra they graduate downwards into the flagstones, and are regularly interbedded with them. As the result of careful mapping of the coast-sections in the southern islands, we have come to the conclusion that Scapa Flow occupies the centre of a geological basin, towards which the strata are inclined on almost every side, and round whose shores the highest members of the Lower Old Red Sandstone in Orkney are to be found. We have elsewhere stated our reasons for believing that the Orcadian flagstones, with the conformable sandstones and marls, are the equivalents of the higher subdivisions of the Caithness series *.

It ought to be clearly borne in mind that to the north-west of the great fault which extends from Houton Head eastwards by Scapa to the bay east of Work Head, the Old Red strata consist wholly of flagstones, save the conglomeratic beds, which repose unconformably on the crystalline axis, north of Stromness.

The physical features as well as the geological structure of Hoy are somewhat different from those which obtain in the other islands. Instead of a low undulating tableland, terminating seawards in a bluff cliff or sloping downwards to a sandy beach, which is the dominant type of Orcadian scenery, the island of Hoy forms a prominent tableland, trenched by a series of deep narrow valleys, which are occasionally flanked by conical hills upwards of 1500 feet high. These narrow valleys must have been admirably adapted for nourishing a series of local glaciers towards the close of the Glacial period, as is evident from the long moraines now strewn over the hill-slopes.

The greater portion of the island is occupied by coarse false-bedded sandstones, which are but the counterpart of the Upper Old Red Sandstones at Dunnet Head, in Caithness. Near the base of this division occur some contemporaneous volcanic rocks, which are admirably exposed on the noble cliff in the north-west of the island

* "The Old Red Sandstone of Orkney," by B. N. Peach and J. Horne. Trans. of the Phys. Soc. Edinb. vol. v. 1880.

and at the base of the Old Man of Hoy. The whole series rests *un*conformably on the flagstones; and in the south-west portion the upper division is brought into conjunction with the lower by a fault which extends from Melsetter to the coast-line opposite Risa island *.

III. Glaciation.

The glacial phenomena of Orkney completely establish the double system of glaciation which we found to obtain in Shetland. There is satisfactory evidence for maintaining that during the primary glaciation the Orkney Islands must have been overridden by a mass of ice which moved from the North Sea to the Atlantic; but towards the close of the Glacial period, when the great *mer de glace* had retreated from the Orcadian coast-line, local glaciers must have lingered for a time in the valleys of Hoy and in some of the more elevated parts of the Mainland.

Though these islands do not comprise any districts that might be compared with North Mavine or the promontories of Lunnasting in Shetland, which are dotted all over with finely preserved *roches moutonnées* and rock-basins, nevertheless a careful search along the cliff-tops reveals numerous instances of glaciated surfaces and ice-markings. The latter, however, are not so abundant as we found to be the case in Shetland, which may be satisfactorily explained by the rapid disintegration of the flagstones when long exposed to atmospheric waste.

In the island of Westra the average direction of the striæ in the eastern part of the island is W. 20°–30° N. Close by Noltland Castle, at the roadside, the trend is W. 20° N., on the north-west face of Cleat hill N.W., and immediately to the east of the same hill W. 30° N. At Rackwik, on the eastern shore, the ice-markings vary from W. to W. 20° N., while in Tuquoy Bay they point W. 10° S.

A careful examination of the striated surfaces on the hills west of Pierowall proves that the ice must have been slightly deflected as it impinged on the eastern slopes, the lower portion moving in the direction of the northern coast-line, while the higher strata streamed westwards over the hill-tops towards Nonp Head and Russitaing. On the north-eastern face of the hill south of Ourness several examples were noted pointing N. 30°–35° W., but in the gap between the hills the direction is W. 5° S.

Perhaps one of the most interesting features connected with the glaciation of Westra is the freshness of the ice-markings on Nonp Head (240 feet) and along the cliff-tops to the south. A few yards to the north and south of the highest point of this bold headland, finely preserved striæ were observed on grey flags, where the thin Boulder-clay had been recently removed by the action of the sea, trending W. to W. 3° N. Above Ramna Gio the direction

* The geological structure of Hoy was solved by Professor Geikie and Mr. B. N. Peach in 1874. See "The Old Red Sandstones of Western Europe," Trans. Roy. Soc. Edinb. vol. xxviii. p. 411; also "The Old Man of Hoy," Geol. Mag. decade ii. vol. v. p. 49.

varies from W. 10° N. to W. 10° S.; at Russitaing, W. 20° S.; near the Red Hare, W. 10° S.; near Inganess, W. 15° S. to W. 18° N.; and again, in the bay south of Inganess, a well-marked instance points W. 12° N.

In some parts of the island of Eda the proofs of glaciation are marvellously fresh, more especially on the surfaces of the harder sandstones. From the finely glaciated surfaces and numerous *roches moutonnées* in the centre of the island north of Lonton it is evident that the ice must have overtopped the hills in its north-westward march. On the east slopes of the Stennie hill the direction of the striæ is W. 20°–25° N., and not far to the south W. 40° N.

Along the eastern coast, between Calf Sound and Lonton Bay, the ice-markings point N. 20°–30° W., while between the Kirk of Skail and the Veness promontory the average direction is W. 35°–40° N. In one remarkable instance, on the shore about a mile to the south of the Kirk of Skail, striæ were observed on a highly inclined rock-face trending north and south, while on the cliff-top the direction is W. 35° N., the former being evidently due to local deflection. Along the western coast the general direction of the ice-movement is in perfect harmony with that just described. In the neighbourhood of Warness, which forms the south-west promontory of the island, the trend is W. 13° N., while to the west of the Wart of Eda, on the cliff-tops, it varies from W. 28° N. to W. 43° N.; and again, to the north of Seal Skerry, W. 40° N. One of the best examples to be met with in the island occurs in the bay east of Fara's Ness, where a small stream enters the sea. This burn has cut down through a deposit of shelly Boulder-clay to the polished pavement on which it rests; and along the stream-course the firm lines produced by the ice-chisel may be seen to advantage on the glaciated surfaces of the sandstones. The direction of these instances is N. 27° W., but on the shore, close by the mouth of the stream, the trend is W. 38° N.

Notwithstanding the widespread covering of blown sand which envelops the greater portion of the island of Sanda, we succeeded in finding abundant traces of the ice-movement. In the Burness peninsula striated surfaces are numerous along the coast-line, about a dozen instances occurring between Hermaness Bay and the Holms of Eyre, which, with one or two exceptions, point W. 10°–15° N. To the west of Loch Roo the direction is W. 25° N.; and not far from the Saville boulder, on the eastern shore of the peninsula, the trend is N.W.

On the shores of Kettletoft Bay the average direction is W. 10° N.; inland from this bay towards the Free Church it varies from W. 20°–40° N., while in Bacaskeal Bay it is N. 32° W. This north-westerly movement is equally borne out by the evidence obtained in the southern part of the island; for in the bay west of Hack Ness the ice-markings point N. 30° W., and on the western shore between Spur Ness and Stranquoy N. 8°–17° W.

The island of Stronsa likewise supplies conclusive evidence regarding the direction of the ice-movement; for in Odin Bay, where an important section of Boulder-clay occurs, which we shall describe presently, the striæ point W. 15°–35° N.; between Kirkbuster and Finga the trend is W. 10°–40° N., at Burgh Head W. 40° N., and north of Holland W. 40° N. On the western coast-line, on the shores of Rousholm Bay, the direction varies from W. 41° N. to N. 40° W.; and on the shores of Linga Sound it is W. 40° N. It is of the utmost importance to note the perfect agreement in the trend of the ice-markings in different parts of this island, because it indicates a persistent movement in one determinate direction.

A careful examination of the striated surfaces on Shapinshay confirms in a remarkable manner the evidence regarding the ice-flow during the primary glaciation in the northern islands. Along the west coast, between Galtness and Stromberryness, the direction varies from W. to N.W., while on the shores of Veantro Bay, which indents the northern part of the island, the markings point N.W. and N. 35°–40° W. Further along the eastern coast-line, between Gioness and the school-house, the direction is W. 30° N., and the same trend is observable southwards towards the church; near Foot striæ were noted pointing N. 30° W., and close to Haco's Ness N. 20° W.

It is impossible, within the limits of this paper, to describe the various instances we met with in the Mainland, and we will therefore merely indicate the general trend in different parts of the island. On the glaciated surfaces of granite and gneiss north of Stromness numerous examples occur trending W. 15°–20° N. and W. 12° S. Immediately behind the town the direction varies from W. 8°–40° N., while on the moorland between Yesnabae and the Loch of Stennis, as well as at the Ring of Brogar, the same variation is observable from W. 12° N. to N.W.

On the hill-slopes overlooking Gorsness and the island of Gairsa the average direction of several examples is N. 25°–30° W., and along the coast-line from Irland Bay to Houton Head the trend varies from W. 12°–42° N. One instance occurs in Irland Bay pointing W. 32° S., which probably belongs to the later glaciation.

In Kirkwall Bay, a short distance to the east of the pier, beautifully striated flagstones may be seen where Boulder-clay has been recently removed by the action of the sea, the striæ running N. 6° W. and N.N.W.; and so also on the surfaces of the flagstones in the Scapa Quarry the direction is N. 8° W. Along the shore from Scapa to Howquoy Head the average direction of several examples is N. 30°-35° W., and near St. Mary's the trend varies from N.W. to N. 25° W.

In the southern islands striæ are not so abundantly found, owing to the readiness with which the soft yellow sandstones and marls crumble away when long exposed to the denuding agencies. In South Ronaldshay several examples occur, the general direction of which is W. 20° N. These may be seen on the cliff-tops near Stow Head and Halcro Head by removing the coating of Boulder-clay. Even on the cliffs of the island of Hoy, overlooking the Atlantic, striated surfaces have been observed by Professor Geikie at a height of 600 or 700 feet above the sea-level.

The evidence now adduced regarding the ice-movement proves beyond all doubt that the islands have been glaciated in one determinate direction, independently of their physical features. A glance at the striæ map accompanying this paper (Pl. XXVII.) shows the remarkable uniformity of the ice-flow in the different islands. Here and there, where local causes interfered with the general movement, slight deflections are met with; but, on the whole, the prevalent direction varies from W.N.W. to N.N.W. A careful examination of the numerous striated surfaces convinced us that the ice-sheet must have crossed the islands from the North Sea to the Atlantic. Indeed no one who reflects for a moment on the physical features of the islands could reasonably attribute the striations to a local radiation of the ice. If we except Hoy, these scattered islands contain no mass of elevated ground which is capable of giving rise to a local ice-sheet. So far from this being the case, we shall have occasion to refer to the absence of any indications of the existence of local glaciers in most of the islands towards the close of the Glacial period, a phenomenon which is doubtless due to this very cause. On the contrary, when we view the persistent north-westerly trend of the striations in connexion with the physical features, when we consider that the glaciated surfaces along the cliff-tops, as well as the *roches moutonnées* on the hill-slopes, prove that the islands must have been overflowed by the ice, we cannot resist the conclusion that the ice-movement during the primary glaciation originated beyond the limits of Orkney.

Fortunately the dispersal of the stones in the Boulder-clay amply confirms the foregoing conclusions regarding the north-westerly movement of the ice, while the presence of Scotch rocks in the same deposit enables us to demonstrate that the ice-sheet which crossed this group of islands must have radiated from the mainland of Scotland.

IV. Boulder-clay.

This deposit is not spread over the general surface of the low undulating tablelands in the form of a more or less continuous covering. It occurs mainly round the bays, where it frequently attains a considerable depth, while the inland districts are covered with a thin clayey soil, due to the decomposition of the underlying flagstones. We shall have occasion to describe one or two sections of Boulder-clay which may be traced continuously along the shore for half a mile, and which are quite undistinguishable from the Lower Boulder-clay of Scotland. Occasionally thin patches of this deposit are to be found on the cliff-tops, containing well-striated stones and foreign rocks, clearly indicating that the islands must have been overflowed by the ice.

In the island of Westra the Boulder-clay is sparingly distributed, but some excellent sections are to be met with round the bays in the southern districts. At Rackwik, near Stangar Head, it consists of a tough tenacious gritty clay, which is chiefly made up of red sandstone fragments, about 80 per cent. of the larger blocks being composed of sandstones which are foreign to the island. Some of these blocks, which are finely smoothed and striated, measure six feet across. The deposit rests on the grey flagstones, and some small subangular fragments derived from the underlying rocks are likewise included; but the great majority of the stones consist of sandstones which we identified as belonging to the island of Eda. Crossing the peninsula to the shores of Tuquoy Bay, similar sections are presented, resting on grey flagstones, the included blocks being composed of the underlying rocks, red sandstones, quartzites, and chalk-flints. It is important to note that the red sandstone blocks do not form such a large percentage at this locality, but that they gradually diminish in number as we recede towards the north-west. On the slopes of Cleat hill fragments of granite, quartzite, diorite, and dolerite are associated with the flagstones in this deposit; while still further north, near the church, blocks of red and white honey-combed sandstone and small pink granite stones were observed in the Boulder-clay in addition to the local rocks.

Along the west coast hardly any Boulder-clay is to be met with; but some thin patches are to be seen on the cliffs at Nonp Head, containing well-striated stones derived from the flagstones of the island. Occasional smooth blocks of Red Sandstone occur in the hollows amongst the débris of the underlying rocks, which are, in all likelihood, the relics of the once existing Boulder-clay.

Now it is evident, on a moment's consideration, that the gradual decrease in number of the red sandstones in the Boulder-clay, as we traverse the island from the south-eastern headlands towards the west coast, indicates that the ice-flow must have been *towards* the Atlantic; and when we consider that these sandstones nowhere occur *in situ* in Westra, and that they could only have been derived from the adjacent islands of Eda and Sanda, we are forced to conclude that the ice-movement must have been altogether independent of the islands.

Along the east coast of Eda the Boulder-clay is not so abundant as in some of the more sheltered bays on the opposite side of the island, which is satisfactorily accounted for by supposing that the rocky slopes facing Eda Sound were exposed to the full sweep of the *mer de glace*. Here and there, however, patches do occur, as on the north shore of Lonton Bay, where the deposit contains smoothed and striated chalk-stones, along with blocks of red and white sandstones and grey flagstones. Its most noteworthy feature is the presence of worn fragments of marine shells, which are scattered irregularly through the stony clay. Similar sections occur in the bay of Calf Sound near the pier, and also along the west coast near the Wart of Eda, where shell-fragments were likewise observed.

Perhaps the finest section of this deposit in Eda occurs along the banks of a small stream which flows into the bay about a mile east of Fara's Ness on the west coast. The stream has cut down through the stony clay to the finely grooved pavement of sandstone, so that the glacialist can examine thoroughly the nature of the deposit. It consists of tough red clay, packed with smooth and striated stones scattered irregularly through the section. There is no trace of stratification in the deposit, as it retains the same tumultuous character throughout. The stones are beautifully striated along the major axis, and are mainly composed of the underlying red and yellow sandstones, varying in size from an inch to several feet across. In addition to these we noted smooth chalk-stones, chalk-flints, and subangular blocks of the grey flagstones. The most interesting feature, however, is the occurrence of small worn fragments of marine shells which are scattered indiscriminately through the deposit; they are smoothed and striated precisely in the same way as the stones in the Boulder-clay, as if they had been subjected to the same abrasion.

Shelly Boulder-clay was also observed on the west coast of Sanda, between Spur Ness and Stranquoy; and sections of the same deposit are to be found in Bacaskeal Bay. In the Burness peninsula, near the Holms of Eyre, the shore is bounded by low cliffs of purple shales and flags, with a coating of Boulder-clay, which is just sufficient to cover the surface of the rocks. It is chiefly composed of fragments of the underlying rocks, but likewise contains fragments of sandstone, granite blocks, and smoothed stones of gneiss and schist, all of which, except the sandstone, are foreign to the island.

In Stronsa several important sections were met with both on the east and west sides of the island. On the shores of Linga Sound, not far from the narrow isthmus of Aith, a section of shelly Boulder-clay occurs resting on grey sandstone, the deposit being upwards of 25 feet thick, and comprising chalk, chalk-flints, and white quartz, in addition to the blocks derived from the flags and sandstones of the island. Further, on the north-east corner of Rousholm Bay a thin coating of this deposit rests on the flagstones, which are bent over to the north-west in the direction of the ice-flow.

One of the best exposures of Boulder-clay in Orkney occurs on the eastern shores of Odin Bay, in Stronsa, where it forms a continuous cliff for nearly half a mile. At intervals the section is obscured by a grassy covering, but every succeediug storm washes anew the face of the cliff, and exposes a fresh surface for examination. The deposit, which varies from 20 to 30 feet in depth, consists of a tough gritty clay of a reddish colour, full of well-smoothed and striated stones, which are mostly of small size. There are few large boulders to be seen, the largest rarely exceeding a foot in diameter. There is not the slightest trace of stratification from one end of the section to the other, as the stones are disposed irregularly through the clayey matrix. By far the greater number of the included blocks have been derived from the flagstones and the sandstones which occur in the neighbourhood; but the following rocks are likewise represented:—granite, pink porphyritic felstone, gneiss, schist, quartzite, white quartz, dark limestone, with abundant plant-remains, which is probably of Calciferous-Sandstone age, oolitic limestone, oolitic calcareous breccia, fossil wood (probably oolitic), chalk, and chalk-flints, all of which are foreign to the island. When we come to collate the evidence regarding the primary glaciation, we shall discuss the probable localities from which these blocks were derived. At present it is sufficient to state that the evidence is clearly in favour of their having been carried from the mainland of Scotland.

Equally important is the presence of numerous fragments of marine shells throughout the deposit. Though we examined the section with the utmost care, we did not succeed in dislodging a complete shell; indeed so worn are the fragments that it was with the utmost difficulty that we obtained specimens sufficiently well preserved for determination. Nearly all the fragments are smoothed and striated, like the stones in the Boulder-clay; and there can be little doubt that these characteristics are due to the very same cause in both cases. Amongst the broken shells we detected fragments of *Cyprina islandica*, *Mytilus*, and *Mya truncata*; but a careful search, after severe storms, by some local collector would certainly increase this list considerably.

In the island of Shapinshay shelly Boulder-clay occurs at various localities on the east coast, as at Kirkton, where it contains finely striated chalk-stones. The best sections, however, occur along the western shore, and especially in the bay south of Galtness, where it forms a bluff cliff washed by high tides. This cliff furnishes valuable evidence regarding the ice-carry, inasmuch as we noted amongst the included stones blocks of the slaggy diabase which occurs *in situ* in the south-east corner of the island, along with striated fragments of the sandstones which are associated with the volcanic rocks. In this section smooth blocks of chalk and oolitic limestone, with numerous fragments of marine shells, were also observed.

If we traverse the Mainland from Scapa and Kirkwall westwards, by the Loch of Stennis, to the crystalline axis north of Stromness, similar conclusive evidence regarding the north-westerly movement of the ice is obtained from the Boulder-clay. On referring to the map of Orkney, it will be seen that the narrow zone of red and yellow sandstones which crosses the Mainland from Inganess to Scapa extends south-westwards along the shore as far as Orphir Kirk. Now, in the shelly Boulder-clay in Kirkwall Bay, to the east of the pier, striated blocks of red sandstone are commingled with the flagstones in the clayey matrix. The latter are by far the most numerous, and are likewise beautifully scratched along the major axis; but the sandstone blocks constitute a fair percentage of the included stones. From the lithological character of these blocks, we had no hesitation in concluding that they had been derived from the sandstones to the east of Kirkwall.

Again, in the sections occurring on the coast between Houton Head and Irland Bay, the observer cannot fail to note the gradual increase in the number of the sandstone blocks in this deposit as he approaches Houton Head, a phenomenon which is quite intelligible when he remembers that the striations along the shore point W.

12°–42° N., the latter being the prevalent direction. Indeed at Houton Head the ice-markings are nearly parallel with the coast-line, so that the sandstone blocks could not possibly have come from Hoy. Blocks of the same rock are strewn on the hill-slopes above Gorsness, to the north-east of Maes Howe. It is a significant fact that not a single block of the granite or gneiss which occurs *in situ* to the north of Stromness and in the island of Graemsa is to be found in the Boulder-clay between Irland Bay and Houton Head, or anywhere to the east of the axis of crystalline rocks; but as soon as the western limit of these rocks is crossed, numerous blocks of granite and gneiss are strewn on the slopes and along the cliff-tops between Brak Ness and Inganess. Had the ice-movement been *from* the north-west, the phenomena would have been precisely the opposite of those we have described.

In the southern islands this deposit is not abundant; but in South Ronaldshay, on the shores of Water Sound, east of St. Margaret's Hope, we observed patches of it containing blocks of sandstone, flags, and chalk, with comminuted shells. In this instance the shells, when being dislodged, crumble readily to a white powder.

Our friend Mr. R. Etheridge, Jun., who kindly examined the shell-fragments we obtained in the Boulder-clay sections in Orkney, informs us that, on account of the fragmentary character of the material, it is impossible to determine many of the specimens. He has, however, named the following:—

Cyprina islandica.
Astarte (hinge).
Saxicava arctica.
Mya truncata.
Mytilus (fragment).

Mr. H. B. Brady, F.R.S., has also kindly determined the following species of Foraminifera from the same deposit:—

Miliolina seminulum, *Linné*.
Lagena sulcata, *W. & J.*
Truncatulina lobatula, *Walker*.
Polystomella striato-punctata, *F. & M.*

V. Moraines.

One conspicuous feature connected with the Glacial phenomena of Orkney is the remarkable absence of any traces of local glaciers except in Hoy and the Mainland. When we consider the abundance of moraine heaps in all the more important islands of the Shetland group, this difference seems all the more striking; but when we remember the marked contrast between the physical features of the two groups of islands, the difficulty at once disappears. As we have already indicated, the only mass of elevated ground which would be capable of nourishing a series of local glaciers, after the great *mer de glace* had melted back from the Orcadian coast-line, occurs in Hoy. Hence we find that in the valleys which drain the group of conical hills in the north of that island moraines occur in abundance and also of great size. Professor Geikie has already described several examples which also came under our notice *. In the valley to the

* 'Nature,' vol. xvi. p. 415.

east of Hoy hill a moraine mound, nearly half a mile long and from fifty to sixty feet high, runs across the mouth of the glen. It would seem that the later glacier which filled the valley did not succeed in scooping out the *moraine profonde* belonging to the primary glaciation, as the moraine matter rests on stiff sandy Boulder-clay. Further, in the hollow below Coulax hill several concentric heaps were observed which extend across the valley, indicating pauses in the retreat of the glacier.

In the Mainland also the moory ground between Finstown and Maes Howe is dotted all over with conical moraine heaps, evidently deposited by the glaciers which moved off the northern slopes of the Orphir hills. On the east side of the range of hills that runs north from Finstown several parallel moraine ridges may be observed not far from Ellibister. Again, in the peninsular tract to the south-east of Kirkwall, a splendid series occurs in a valley situated about three miles north of Graemshall. At the point where the highroad from Roseness joins that from St. Mary's to Kirkwall, the concentric arrangement of the moraine heaps is admirably displayed.

VI. Erratics.

Boulders do not occur very plentifully in Orkney; but we felt convinced, from an examination of those we met with, that they must have been mainly distributed during the primary glaciation. In Westra blocks of granite and quartzite are found on the slopes of Cleat hill; and rounded stones and boulders of red sandstone from Eda occur in the southern district as well as along the western shores.

In the north of Sanda, at Saville, a remarkable boulder of gneiss is met with, which has been described by previous observers. It measures $6\frac{1}{2} \times 6 \times 2\frac{1}{2}$ feet above ground, but its base is buried underneath the surface. Professor Heddle, who has made a minute examination of this boulder, states that it does not appear to be a British rock. He gives the following description of it in a recent number of the 'Mineralogical Journal'*:—"It consists in greatest amount of white finely striated oligoclase, the crystals of which are penetrated by fine filaments of actinolite, glassy quartz in much smaller amount, dark green finely foliated lustrous hornblende in well-marked crystals, very little of a pale-green mica, a minute amount of a pale-brown mineral, which may, but does not appear to be sphene, and a speck or two apparently of thorite. The mass also contains a single crystal of pale-green apatite four or five inches in length by over an inch in width, and this apatite contains imbedded cryptolite."

He states that the only Scotch rock resembling the Saville boulder which he is aware of is to be found in Sutherlandshire; but it has orthoclase as its felspar, and does not contain apatite. Should this boulder really prove to be of Scandinavian origin, its presence

* Mineralog. Journal, vol. iii. p. 174.

has an important bearing on the questiom of the extension of the ice in the North Sea. Some smaller blocks of gneissose rocks occur in the neighbourhood. A few boulders of conglomeratic sandstones occur in Eda, which may be purely local.

On the Mainland blocks of white and reddish-grey sandstone are strewn on the hill-slopes north of Finstown and on the moory ground south of Maes Howe, which have been derived from the north-west shore of Scapa Flow; and so also along the west coast, between Brak Ness and Inganess, north of Hoy Sound, boulders of granite and gneiss are met with on the flagstone area to the west of the axis of crystalline rocks.

VII. Conclusion.

The evidence now adduced regarding the glacial phenomena of Orkney is of the utmost importance in solving the question of the extension of the ice in the North Sea. We have already referred to the remarkable uniformity in the trend of the ice-markings throughout the islands, which, with certain exceptions, vary from W.N.W. to N.N.W. From the manner in which these striations maintain their persistent north-west trend, irrespective of the physical features of the country, it is evident that the agent which produced them must have acted independently of the islands.

Nay, more, the dispersal of the stones in the Boulder-clay leaves no room for doubt that the ice-sheet must have crossed the islands from the North Sea to the Atlantic. It is no doubt true that the lithological varieties of the Orcadian rocks are not so numerous as in Shetland, and hence the corroborative evidence of the north-westerly movement is not so abundant. Still in those cases where the geological structure of the ground permitted us to test with certainty the direction of the ice-carry, we were driven to the conclusion that the ice-flow must have been towards the Atlantic. In Westra the Boulder-clay sections contain striated blocks of red and white sandstone, which have been derived from Eda, and it is particularly observable that they diminish in number as we move towards the north-west. In Shapinshay blocks of the slaggy diabase from the south-east corner of the island occur in the Boulder-clay near Galtness; and so also in the Mainland, the red and white sandstones which cross the centre of the island are represented in the *moraine profonde* on the shore between Houton Head and the Loch of Stennis. Yet, again, to the west of the axis of crystalline rocks at Stromness, smoothed blocks of gneiss and granite are found in considerable abundance.

Fortunately, however, we have additional evidence which enables us to demonstrate, not only that the ice-movement must have been from the North Sea towards the Atlantic, but, what is of still greater moment, that the ice which glaciated Orkney must have come from Scotland. In the numerous sections of Boulder-clay described in this paper we have had occasion to refer to the occurrence of smoothed and striated stones of dark-grey limestones full of plant-remains, oolitic limestone, calcareous breccia, chalk, chalk-flints, fossil wood, pink granite, porphyritic felstone, &c., all of which are foreign to the islands.

According to the opinion of Mr. Carruthers, F.R.S., the blocks of dark-grey limestone with plant-remains in all probability belong to the Calciferous Sandstone series. He has identified a well-marked specimen of *Lepidostrobus* in one of the blocks, though it is not distinct enough to be named specifically. Lithologically the boulders resemble some of the thin limestone bands in the Cementstone series of Central Scotland; and the nearest locality to Orkney where these rocks occur *in situ* is in the county of Fife. With reference to the Secondary rocks, Professor Judd, F.R.S., states that, besides the chalk and chalk-flints, he detected amongst our collection some specimens which resemble some of the Secondary rocks of Scotland. Two specimens of the calcareous breccia from the Boulder-clay in Odin Bay "very closely resemble parts of the Upper Oolites of Sutherland," and two other blocks are probably from the same locality. Moreover, he adds that the specimens of oolitic limestone very possibly come from some part of the Secondary series in Scotland.

In addition to these, we observed, in the Odin-Bay section, large blocks of a remarkable rock which seems to be petrified wood. It has a curious fibrous structure and is very calcareous; indeed under the microscope it appears to be mainly made up of crystals of calcite, though occasionally there are portions where the structure is still retained. Blocks of the same rock, however, occur in the Caithness Boulder-clay, which show traces of organic structure under the microscope. On dissolving a small piece of the rock a large residue of coaly matter was obtained, which ignited with a strong flame. It would appear that this rock is largely burnt for lime in Sutherlandshire, where it is washed out of the Oolitic shales.

In all probability most of the blocks of granite, felstone, gneiss, quartzite, and schist which occur throughout Orkney, save those in the Stromness district, have been derived from the north-east of Scotland, though they possess no special characteristics which might enable us to identify them with any particular locality.

Now it ought to be borne in mind that chalk, chalk-flints, and various rocks of Jurassic age are found in the Boulder-clay of Caithness, and also in the same deposit in the low grounds of Banffshire and Aberdeenshire, where it possesses the same physical characters as in Orkney, and likewise contains fragments of shells. It seems perfectly reasonable to conclude, therefore, that the Boulder-clay in these widely separated localities must be ascribed to a common cause, or, in other words, to the action of land-ice. Indeed no one who attentively examines the sections in Orkney would ascribe them to the action of icebergs or coast-ice. We have already discussed the objections to the marine origin of the Shetland till, and the very same arguments apply with equal force to the present case.

Moreover, on referring to the chart showing the probable path of the ice in the North Sea, which accompanies this paper (Pl. XXVII.), it will be seen that it is impossible to escape this conclusion. The ice, which radiated from the north-east of Scotland, not only filled the basin of the Moray Firth, but likewise spread over the low grounds of Banffshire and Aberdeenshire. The researches of previous investigators point to this conclusion; and quite recently, during the prosecution of the Geological Survey of the south side of the Moray Firth, additional facts have transpired which tend to confirm it. Further, in the neighbourhood of Dunbeath, on the Caithness coast, the striæ gradually swing round till they run parallel with the shore, eventually bending inland till they point towards the north-west, in harmony with the trend of the ice-markings in Orkney. Clearly, then, the ice must have been deflected so as to override the low grounds of Caithness, as pointed out long ago by Dr. Croll. Similarly in Forfarshire and Kincardineshire, the ice which moved off the south-east slopes of the Grampians, on reaching the coast-line, was bent round in a N.N.E. direction, as indicated on the chart. A glance at the chart will also show how the land-ice was deflected along the south-east coast of Scotland, as described by our colleague Dr. James Geikie, F.R.S. Now these marked deflections undoubtedly point to some opposing force which was capable of overcoming the seaward motion of the Scotch ice-sheet. Had it been allowed to follow its natural pathway then the phenomena would have been widely different.

The results of our investigations in Shetland prove that the Scandinavian *mer de glace* not only invaded the North Sea, but likewise overlapped that group of islands in its march to the Atlantic. The presence of this mass in the bed of the German Ocean furnishes a satisfactory explanation of the phenomena above referred to; for the two ice-sheets must have coalesced on the sea-floor, and the combined ice-field would naturally take the path of least resistance. In other words, one portion would flow north-westwards by the Orkney Islands, while the southern portion would flow in the direction of the English coast, as laid down on the chart. In all probability the dividing line would be somewhere opposite the basin of the Forth.

We can quite well understand therefore how the Scotch ice-sheet, as it crept outwards along the bed of the Moray Firth towards the North Sea, must have pushed along the marine shells and silt which it encountered on the sea-floor. These would be commingled with the *moraine profonde* which had gathered underneath the ice-sheet; and the shells would ultimately be smoothed and striated precisely like the stones in the bottom moraine. Hence the occurrence of Scotch rocks together with shell-fragments in the Orkney Boulder-clay is what we would naturally expect; and in the light of the foregoing reasoning all difficulty as to the explanation of the phenomena disappears. It is not necessary for us to assign the precise localities from which the various foreign rocks have been derived; it is sufficient for our present purpose if we show, as has been done, that they may have come from the basin of the Moray Firth or the eastern counties of Scotland lying to the north of the basin of the Forth. The presence of blocks of limestone of Calciferous-Sandstone age in the Odin-Bay section in Stronsa seems to indicate that a portion of the ice which crossed Fife was deflected to the north; and even if the Saville boulder should prove to be of Scandinavian origin, its position in the north of the group is quite in keeping with the path which would be followed by the Scandinavian ice.

It is a significant fact that nowhere in the Shetland Boulder-clay did we find a vestige of the Secondary rocks of Scotland; and though the evidence is merely negative, it nevertheless confirms the foregoing conclusions. We are inclined to believe also that the absence of marine shells in the same deposit, which we noted in our previous paper, may probably indicate that a portion of the present sea-floor round Shetland formed dry land during the climax of glacial cold. We see, therefore, how the glacial phenomena of Orkney furnish a striking confirmation of the views advocated by Dr. Croll more than ten years ago.

Though we visited nearly all the islands of the group and traversed the greater part of the coast-line, we found no trace of gravel kames or raised beaches indicating recent changes in the relative level of sea and land.

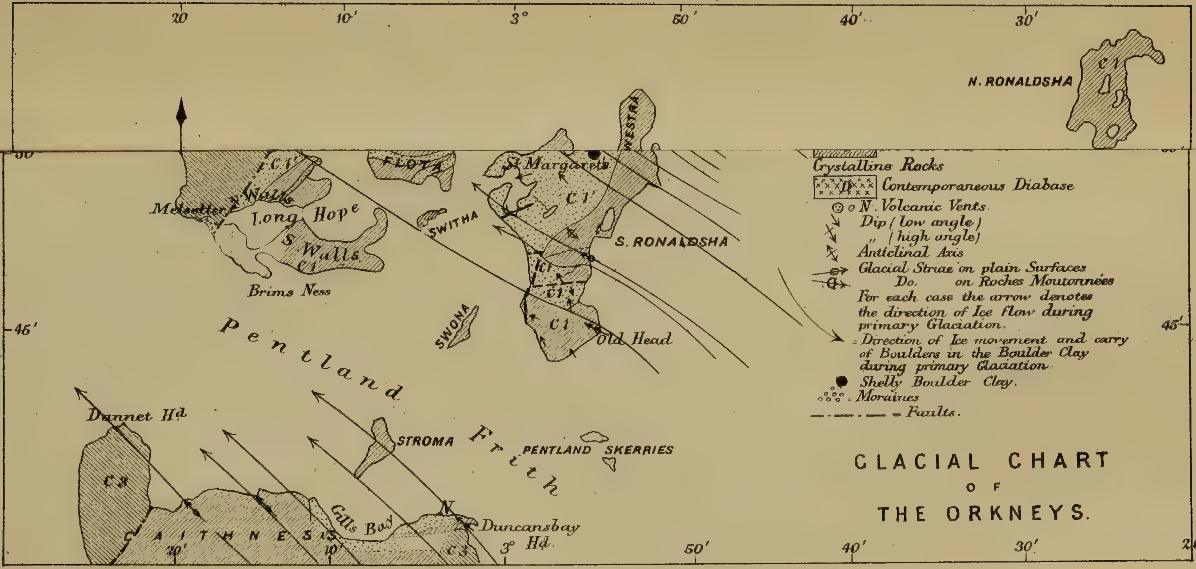
EXPLANATION OF THE PLATES.

PLATE XXVI.

Glacial Chart of the Orkneys.

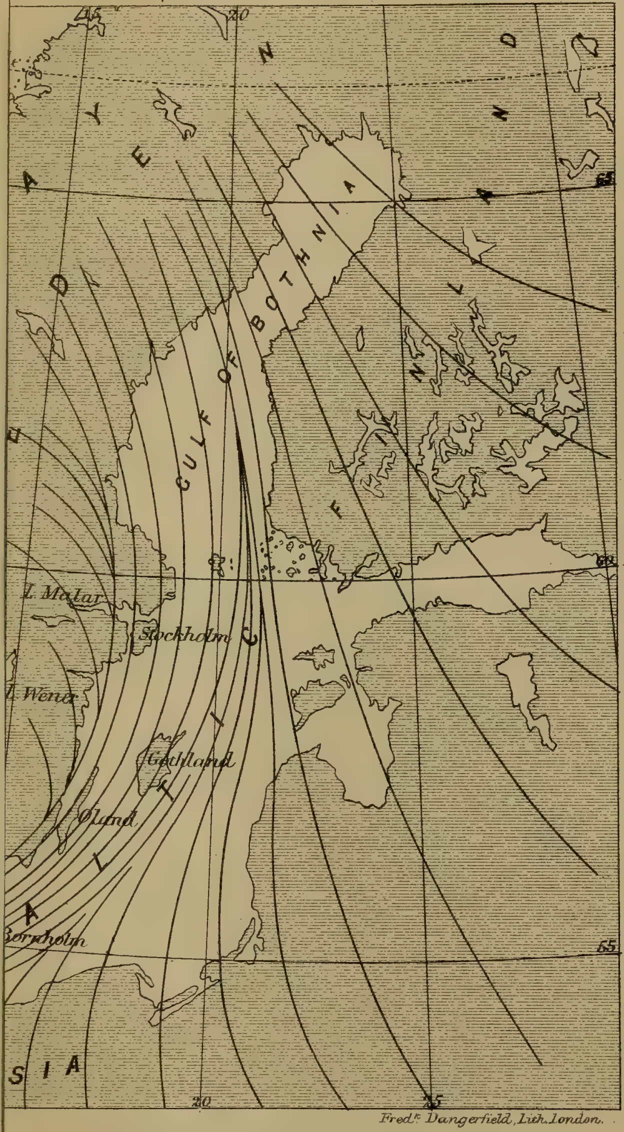
PLATE XXVII.

Chart showing the probable path of the ice in the North Sea.

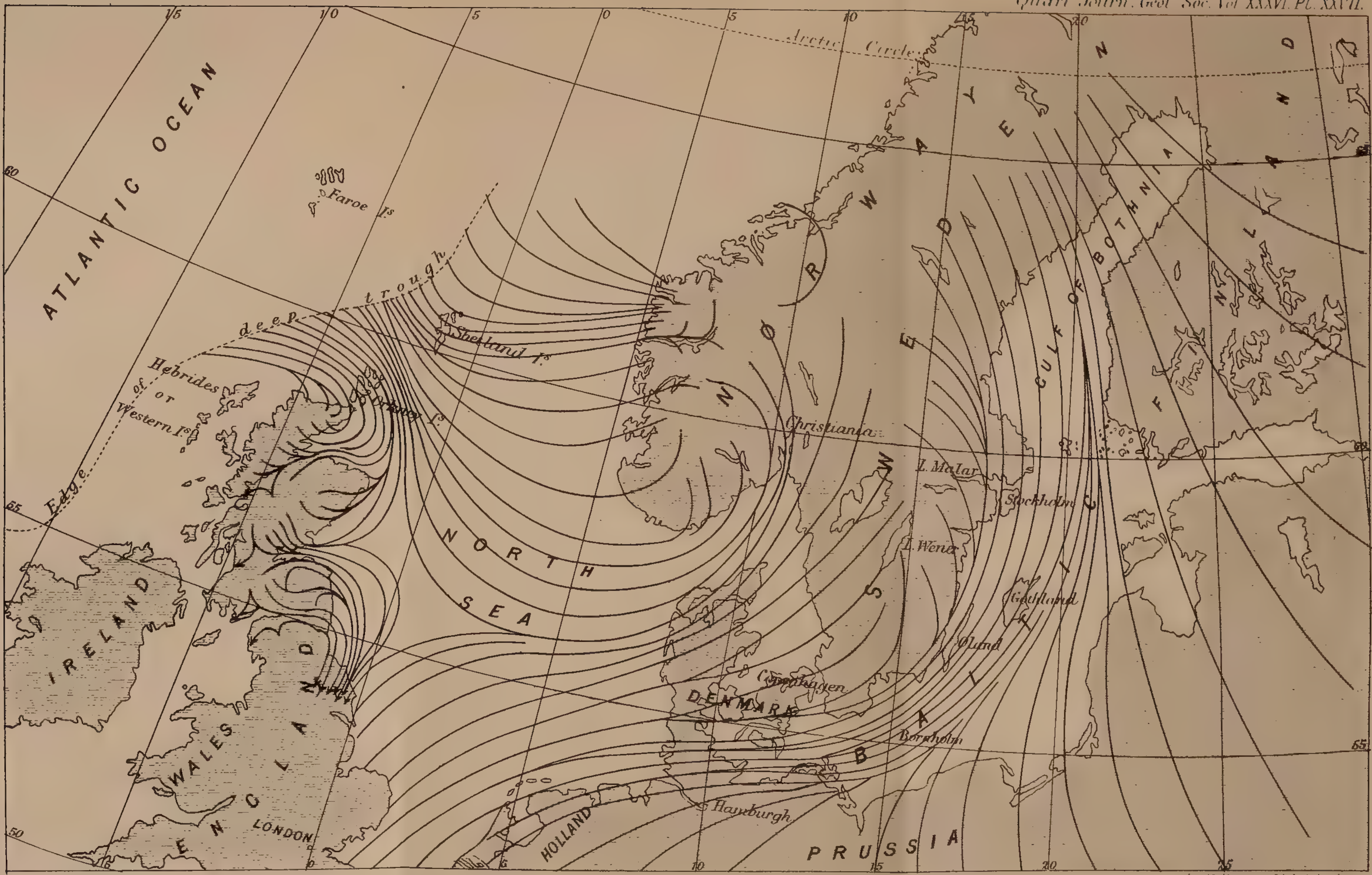


Fredk. Dangerfield Lith. London.


Scale of English Miles
0 1 2 3 4 5 6 7 8 9 10
N. RONALDSHA
PAPA WESTRA
Noup Hd
Pierowall
WESTRA
Rackwick
Holms of Eyre
Boulder of Gneiss about 8 tons
Start Pt
SANDA
Kettletaft
Red Hd
HOLM OF FARA
EDA
Rapness
FARA
20-30
Spurness
Farus Ness
EDA
Skail Kirk
PAPA STRONSA
ROWSA
Brough of Birsay
Warness
Odinness
Odin Bay
STRONSA
POMONA OR MAINLAND
Skail
EYRE
GAIRSA
SHAPINSHA
AUSKERRY
Castle of Yesnabie
Ring of Stennis
Standing Stones
Phinston
Hacco's Ness
Inganess
Inganess
Kirkwall
Moul Hd
Stromness
Brak Ness
Deerness
Hoy Hd
GREMSA
Scapa Bay
COPINSHA
Old Man of Hoy
Houton Hd
CAVA
Scapa Flow
Rackwick
HOY
RISA
LITTLE FARA
Holm Sd
Roseness
BURRA
Pan Hope
FLOTA
Water Sound
Boulder Clay
St Margaret's
Melsetter
N. Walls
Long Hope
S. Walls
SWITHA
S. RONALDSHA
Brims Ness
SWONA
Old Head
Pentland Frith
Dunnet Hd
STROMA
PENTLAND SKERRIES
Gills Bay
Duncansbay Hd
CAITHNESS
Explanation.
Upper Old Red Sandstone Series
Sandstone Group
Flaggy Group
Lower Old Red Sandstone Series
Pre-Old-Red - Sandstone Rocks
Crystalline Rocks
Contemporaneous Diabase
N. Volcanic Vents
Dip (low angle)
" (high angle)
Anticlinal Axis
Glacial Striae on plain Surfaces
Do. on Roches Moutonnées
For each case the arrow denotes the direction of Ice flow during primary Glaciation.
Direction of Ice movement and carry of Boulders in the Boulder Clay during primary Glaciation.
Shelly Boulder Clay.
Moraines
Faults.
GLACIAL CHART OF THE ORKNEYS.



CE IN THE NORTH SEA.



Fredk Dangerfield Lith. London.

CHART SHOWING THE PROBABLE PATH OF THE ICE IN THE NORTH SEA.

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. XXXVI.

Printed by Taylor and Francis, Red Lion Court, Fleet Street.

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1879–80.

November 5, 1879.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Henry Bruce Armstrong, Esq., 25 Saville Row, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the probable Temperature of the Primordial Ocean of our Globe." By Robert Mallet, Esq., F.R.S., F.G.S.

2. "On the Fish-remains found in the Cannel Coal in the Middle Coal-measures of the West Riding of Yorkshire, with the Description of some new Species." By James W. Davis, Esq., F.G.S., &c.

3. "On the Skull of *Argillornis longipennis*, Owen." By Prof. R. Owen, C.B., F.R.S., F.G.S., &c.

November 19, 1879.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Edmund Knowles Binns, Esq., 216 Heavygate Road, Sheffield; and John Dawson, Esq., 11 Somerset Place, Bath, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "Supplementary Note on the Vertebræ of *Ornithopsis*, Seeley (=*Eucamerotus*, Hulke)." By J. W. Hulke, Esq., F.R.S., F.G.S.

2. "On the Concretionary Patches and Fragments of other Rocks sometimes contained in Granite." By J. Arthur Phillips, Esq., F.G.S.

3. "Certain Geological Facts witnessed in Natal and the Border Countries during nineteen years' residence." By the Rev. George Blencowe. Communicated by the Rev. H. Griffith, F.G.S.

December 3, 1879.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Syed Ali, Esq., B.A., Hyderabad, Deccan, India; Wynne Edwin Baxter, Esq., 208 High Street, Lewes, Sussex; Arthur Robert Boyle, Esq., Engineers' Office, Lime-Street Station, Liverpool; Rev. John Lowry Carrick, M.A., Spring Hill, Southampton; Prof. Edward Waller Claypole, Antioch College, Yellow Springs, Ohio, U. S. A.; Rev. T. Dowen, Newlands Terrace, Bootle, Liverpool; Rowland Gascoyne, Esq., Mexborough, near Rotherham, Yorkshire; George M. Henty, Esq., Georgetown, Colorado, U. S. A.; John Marshall, Esq., F.R.A.S., Albion Place, Leeds; Josiah Martin, Esq., Three-Kings College, Auckland, New Zealand; Charles Maxted, Esq., Providence Cottage, Well Road, Hampstead, N.W.; Edward Provis, Esq., M.A., Worcester Street, Bromsgrove; Thomas William Rumble, Esq., The Cottage, East Hill, Wandsworth, S.W.; Rev. John Reuben Taft, St. George's, Wolverhampton; Octavius Albert Shrubsole, Esq., Reading; Samuel Richard Smyth, Esq., 3 Blenheim Terrace, Old Trafford, Manchester; and William Neish Walter, Esq., Hillpark Terrace, Newport, Fife, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "The Gneissic and Granitoid Rocks of Anglesey and the Malvern Hills." By C. Callaway, M.A., D.Sc., F.G.S.; with an Appendix on the Microscopic Structure of some of the Rocks, by Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

[Abstract*.]

The author described the results of his investigations into the stratigraphy and petrology of the above districts, which have led him to the following conclusions:—(1) The granitoid (Dimetian) rocks of Anglesey pass down into an anticlinal of dark gneiss (above) and grey gneiss (below). (2) Associated with the granitoid series are bands of felsite, hälleflintas, and felspathic breccias. (3) The succession of gneissic and granitoid rocks in Anglesey resembles so closely the metamorphic series of Malvern as to justify the correlation of the two groups. (3) The Pre-Cambrian rocks of Anglesey

* This paper has been withdrawn.

and the Malverns, from the highest known member down to the base of the gneiss, may be thus classified:—A. Pebidian (to be described hereafter); B. Malvernian—(*a*) Dimetian, with associated quartz-felsites and hälleflintas (Arvonian), passing down into (*b*) Lewisian.

Discussion.

Dr. Hicks stated that he had always considered the hornblendic series as part of the Dimetian series, and had so marked it in his map, so that he did not think this paper touched his work. He had thought that Dr. Callaway was going to place most of the schist of Anglesey below the above series, but that he did not find stated in the paper. He had for a long time believed that the Malvern series could be correlated with some of the Anglesey rocks. He had long since examined that series. He described some sections exhibited in the Malvern hills, and expressed his disagreement with the author's views.

Mr. Rutley asked whether granitoidite was an arkose or not.

Prof. Duncan asked what the last speaker would call the rock. He said that Dr. Holl might claim priority in the character of the Malvern rocks. He asked whether felspar similar to that found in the Malvern rocks had been found in Anglesey. He thought it was difficult to distinguish rocks by their mineralogical characters.

Mr. Rutley, in answer to Dr. Duncan, stated that he had not examined the rock, but that the description would lead him to regard it as arkose.

Prof. Bonney explained the sense in which he had suggested the term granitoidite, and said that he could not agree with Dr. Hicks in his reading of the Malvern hills.

Prof. Hughes asked whether Dr. Callaway had made out the relation of the schists near Craig yr allor, indicated on his ground plan, to those shown in his section, in which schists were represented as faulted against the rocks of the central axis.

The President, in calling on Dr. Callaway to reply, stated that he thought great caution was needed in identifying rocks far apart by their mineral character.

Dr. Callaway said he did not attach so much value to mineralogical character as to succession. He had avoided some of the larger questions because he wished to proceed with caution, and so mentioned first those which he was most sure about. He maintained that the gneiss rocks which he had described were quite distinct from the Dimetian, were of greater antiquity, and were developed in the Menai anticlinal as well as in the central "axis." He had fully accorded priority to Dr. Holl in the character of the Malvern series. Prof. Hughes had missed his chief point, that at Craig yr allor the schists were *not* faulted against the granitoid rock, but passed up into it.

2. "Petrological Notes on the Neighbourhood of Loch Maree." By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

3. "On some undescribed Comatulæ from the British Secondary Rocks." By P. Herbert Carpenter, M.A., Assistant Master at Eton College.

December 17, 1879.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

James Booth, Esq., The Grange, Ovenden, Halifax; P. N. Bose, Esq., B.Sc., 35 Colville Square, W.; Edgar S. Cobbold, Esq., Chasewood Lodge, Ross, Herefordshire; D. M. Ford Gaskin, Esq., Town Hall, St. Helens, Lancashire; John Farran Penrose, Esq., Parkhenver, Redruth, Cornwall; Stephen Seal, Esq., Coxbench House, Darfield, near Barnsley; Thomas Tate, Esq., Rushton Villas, Thornbury, Bradford, Yorkshire; and Richard Taylor, Esq., Marske-by-the-Sea, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "A Contribution to the Physical History of the Cretaceous Flints." By Surgeon-Major G. C. Wallich, M.D. Communicated by the President.

2. "Undescribed Fossil Carnivora from the Sivalik Hills, in the Collection of the British Museum." By P. N. Bose, Esq., B.Sc. Communicated by Prof. J. W. Judd, F.R.S., Sec.G.S.

January 7, 1880.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Edward Bagnall Poulton, Esq., Jesus College, Oxford, was elected a Fellow; and Prof. A. E. Nordenskiöld, Stockholm, and Prof. F. Zirkel, Leipzig, Foreign Members of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Portland Rocks of England." By the Rev. J. F. Blake, M.A., F.G.S.

2. "On the Correlation of the Drift-deposits of the N.W. of England with those of the Midland and Eastern Counties." By D. Mackintosh, Esq., F.G.S.

January 21, 1880.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Robert Bell, Esq., 20 Burghley Road, Highgate Road, N., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The President announced that an application had been made to the Council by the President of the Philological Society for assistance in perfecting an English Dictionary, in which it is proposed to show the history of the various words. With regard to geological and mineralogical terms he was especially anxious to obtain assistance in ascertaining their earliest employment. Fellows of the Society who were willing to cooperate in this work could communicate with the President of the Philological Society (Dr. Murray, Mill Hill, Middlesex, N.W.).

The following communications were read:—

1. "On the Genus *Pleuracanthus*, Agass., including the Genera *Orthacanthus*, Agass. & Goldf., *Diplodus*, Agass., and *Xenacanthus*, Beyr." By J. W. Davis, Esq., F.G.S.

2. "On the Schistose Volcanic Rocks occurring on the west of Dartmoor, with some Notes on the Structure of the Brent-Tor Volcano." By Frank Rutley, Esq., F.G.S.

3. "On Mammalian Remains and Tree-trunks in Quaternary Sands at Reading." By E. B. Poulton, Esq., F.G.S.

The following specimens were exhibited:—

Microscopic sections and a specimen of Schalstein from Nassau, exhibited by John Arthur Phillips, Esq., F.G.S.

Artificially formed Siliceous Stalactites and Concretions, exhibited by E. A. Pankhurst, Esq.

Cape Diamonds and specimens of Mr. Mactear's artificial crystals, exhibited by Prof. Tennant, F.G.S.

A specimen from Brent Hill, exhibited by W. G. Thorpe, Esq., F.G.S.

Specimens in illustration of their respective papers, exhibited by Messrs. J. W. Davis, F. Rutley, and E. B. Poulton.

February 4, 1880.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Francis Bond, Esq., M.A., Snowdon House, John Street, Hampstead, N.W.; Charles Herbert Cobbold, Esq., San Valentino, Abruzzo Citeriore, Italy; Frank Crisp, Esq., LL.B., B.Sc., F.L.S., 5 Lansdowne Road, Notting Hill, W.; William Henry Dover, Esq., Myrtle Grove, Keswick; Mirza Mehdy Khan, Chudder Ghaut, Hyderabad, Deccan, India; John Notman, Esq., Parliament Buildings, Toronto, Ontario; and John Evelyn Williams, Esq., C.E., Boston, Lincolnshire, were elected Fellows of the Society.

The List of Donations to the Library was read.

A series of Geyserites were presented to the Museum by Dr. F. V. Hayden, F.M.G.S.; and casts of the Three-toed Footprints from the Triassic Conglomerate of South Wales were presented by W. J. Sollas, Esq., F.G.S.

The President announced that, according to a circular, copies of which had been sent to the Society, certain old students of Freiberg were endeavouring to collect the means for erecting a monument in Freiberg to the memory of the late Prof. Bernhard von Cotta, and, further, of establishing a Fund for the assistance of needy students at the Mining Academy of that place.

The following communication was read:—

"On the Oligocene Strata of the Hampshire Basin." By Prof. John W. Judd, F.R.S., Sec.G.S.

ANNUAL GENERAL MEETING,

February 20, 1880.

Henry Clifton Sorby, Esq., LL.D., F.R.S., President, in the Chair.

Report of the Council for 1879.

In presenting their Report for the year 1879, the Council of the Geological Society regret that, probably owing mainly to the continuance of that commercial depression to which they adverted in their last Report, they have to announce to the Fellows that the Society has not regained that material prosperity which it enjoyed during several preceding years.

The number of new Fellows elected during the year is the same as in 1878, namely 55, of whom, however, only 40 paid their fees before the end of the year, making, with 5 previously elected Fellows who paid their fees in 1879, a total accession during the year of only 45 Fellows. On the other hand we have the loss by death of 29, and by resignation of 15 Fellows, whilst 3 Fellows were removed from the list for non-payment of contributions, making a total loss of 47 Fellows. Thus, on the year, there is an actual decrease of 2 Fellows. But as, of the 29 Fellows deceased, 6 were compounders, and 14 non-contributing Fellows, the number of contributing Fellows is increased by 5, being now 744.

The total number of Fellows and Foreign Members and Correspondents was 1416 at the end of the year 1878, and 1415 at the end of the year 1879.

During the year 1879 intelligence was received of the death of 5 Foreign Members; and 3 of the vacancies thus caused, with the 2 existing at the end of 1878, were filled up in the course of the year, leaving at its close 2 vacancies in the list of Foreign Members. The 5 vacancies thus produced in the list of Foreign Correspondents, and that existing at the close of 1878, were all filled up during the year.

The continuance, and indeed partial aggravation of the unfavourable conditions referred to in the last Report of the Council, manifested in the numerical statements already given, shows itself very clearly in its effect on the financial position of the Society. The total Receipts for the year 1879 (exclusive of Mr. Ellis's legacy of £1000) were only £2466 5*s.* 1*d.*, but still £45 6*s.* 5*d.* more than the estimated Income for the year. The total Expenditure, on the other hand, was £2527 2*s.* 8*d.*, or £28 15*s.* 2*d.* below the estimate for the year, although still showing an excess of Expenditure over Income of £60 17*s*. 7*d*. The estimated excess at the last Annual Meeting was £134 18*s*. 4*d*.

The Council have to announce the completion of Vol. XXXV. of the Quarterly Journal and the commencement of Vol. XXXVI.

The Council have further to announce that the Catalogue of the Library is completed, and is now in the Printers' hands. It is estimated to make a volume of over 500 pages, and will be issued to the Fellows at the price of five shillings. The Council hope that the usefulness of this volume as a guide to the contents of the Library, will lead to its being very generally purchased by the Fellows, so that the cost of its production may speedily be repaid. To meet the immediate expense of printing, &c., the Council propose to sell out the necessary amount of the Stock belonging to the Society; the sum thus employed to be replaced by the investment of the amounts realized by the sale of the Catalogue.

The Council have awarded the Wollaston Medal to Professor A. Daubrée, of Paris, a Foreign Member of the Society, in recognition of his long and arduous work in Geology, and especially on the formation of minerals and the metamorphism of rocks.

The Murchison Medal and the proceeds of the Murchison Donation Fund have been awarded to Robert Etheridge, Esq., F.R.S., F.G.S., in recognition of his distinguished services to Palæontology, especially in the preparation of his most valuable Catalogue of British Fossils, and to assist him in the completion of that work.

The Lyell Medal, with the sum of Twenty Guineas from the proceeds of the Fund, has been awarded to John Evans, Esq., LL.D., F.R.S., F.G.S., in recognition of his distinguished services to Geological Science, especially in the department of Post-tertiary Geology.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to Thomas Davies, Esq., F.G.S., as a testimony of the value of his researches in Mineralogy and Lithology, and to assist him in the further examination of the Microscopic structure of Rocks.

The balance of the proceeds of the Lyell Donation Fund has been awarded to Professor Quenstedt, of Tübingen, a Foreign Member of the Society, in recognition of his distinguished services to Mineralogy and Geology, and to assist him in the publication of his great work 'Die Petrefactenkunde Deutschlands.'

In pursuance of the resolution announced in the final paragraph of their last Annual Report, the Council have procured from Mr. Swift an excellent binocular Microscope for the use of the Fellows of the Society, the cost of which (£33 10*s*.) has been paid out of the proceeds of the Barlow-Jameson Fund. The instrument is such as to be available for any kind of microscopic work; but it has been furnished with appliances which fit it specially for petrographical purposes.

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 110 volumes of separately published works and 278 Pamphlets and separate impressions of Memoirs; also about 90 volumes and 75 detached parts of the publications of various Societies, and 15 volumes of independent Periodicals presented by their respective Editors, besides 10 volumes of Newspapers of different kinds. This will constitute a total addition to the Society's Library, by donation, of about 237 volumes and 278 Pamphlets.

A considerable number of Maps, Plans, and Sections have been added to the Society's collection by presentation from various Geological Surveys, from the Ordnance Survey of Great Britain, and from the French Dépôt de la Marine. These amount in all to 160 sheets.

The Books and Maps just referred to have been received from 136 personal Donors, the Editors or Publishers of 15 Periodicals, and 130 Societies, Surveys, or other Public Bodies, making in all 281 Donors.

By Purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 47 volumes of Books, and of 55 parts (making about 8 volumes) of Periodicals, besides 46 parts of works published serially, the commencements of which were obtained in previous years. Two Sheets of the Geological Survey Map of France have been received during the year.

The cost of Books and Periodicals during the year 1879 was £63 13*s.* 3*d.*, and of Binding £62 16*s.* 1*d.* The sum of £11 1*s.* was also expended for Cards for the preparation of the Catalogue, and for a Library Loan-book, making in all £157 10*s.* 4*d.*

The Books in the Society's Library are 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.

As great inconvenience has been experienced from there being no definite time appointed for the necessary annual cleaning of the Library and the books contained in it, the Library Committee recommend that the Library be closed annually for this purpose during the first fortnight of the month of September, that being the time when the Society's rooms are least visited by the Fellows.

Museum.

The Collections in the Museum remain in the same condition as at the date of the last Report of the Committee.

Very few additions to the Museum have to be recorded. They include:—A series of Rock-specimens from the Lower Cambrian Rocks of Shropshire, presented by C. Callaway, Esq., D.Sc., F.G.S., in illustration of his paper on those rocks; a block of Coal from the New Douglas Mine, Nanaimo, Vancouver Island, presented by the Vancouver Coal-mining and Land Company; and a collection of Geyserites (Sinters) from the Colorado Hot Springs, presented by Dr. F. V. Hayden, F.M.G.S.

W. J. Sollas, Esq., M.A., F.G.S., also presented a series of Casts of the three-toed footprints in the Triassic Conglomerate of South Wales, described by him in a paper read before the Society.

COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE CLOSE OF THE YEARS 1878 AND 1879.

	Dec. 31, 1878.		Dec. 31, 1879.
Compounders	308	......	313
Contributing Fellows	739	......	744
Non-contributing Fellows	289	......	277
	1336		1334
Honorary Members	3	......	3
Foreign Members	38	......	38
Foreign Correspondents	39	......	40
	1416		1415

General Statement explanatory of the Alterations in the Number of Fellows, Honorary Members, &c. at the close of the years 1878 *and* 1879.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1878			1336
Add Fellows elected during former year and paid in 1879			5
Add Fellows elected and paid in 1879			40
			1381
Deduct Compounders deceased		6	
Contributing Fellows deceased		9	
Non-contributing Fellows deceased		14	
Contributing Fellows resigned		15	
Contributing Fellows removed		3	
		—	47
			1334
Number of Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1878		80	
Deduct Foreign Members deceased	5		
Foreign Correspondents elected Foreign Members	5		
	—	10	
		70	
Add Foreign Members elected	5		
Foreign Correspondents elected	6		
	—	11	
		—	81
			1415

Deceased Fellows.

Compounders (6).

J. Harper, Esq.
T. Longman, Esq.
G. F. Playne, Esq.
J. Pulleine, Esq.
Sir R. R. Vyvyan, Bart.
S. L. Waring, Esq.

Resident and other Contributing Fellows (9).

J. S. Crossley, Esq.
C. Falconer, Esq.
Capt. H. A. Gun.
R. W. Hall, Esq.
S. Higgs, Esq.
C. Judd, Esq.
T. Sopwith, Esq.
W. R. Williams, Esq.
Sir G. Wingate.

Non-contributing Fellows (14).

S. Benson, Esq.
G. Crane, Esq.
J. S. Dawes, Esq.
F. Finch, Esq.
I. Fletcher, Esq.
W. S. Gibson, Esq.
J. Gurdon, Esq.
W. Harrison, Esq.
J. W. Kirshaw, Esq.
Prof. J. Nicol.
D. Page, Esq.
G. Robbins, Esq.
Sir W. C. Trevelyan, Bart.
Sir G. Wingate.

Foreign Members (5).

Dr. J. F. Brandt.
Prof. B. von Cotta.
Prof. B. Gastaldi.
Prof. Paul Gervais.
Prof. A. Sismonda.

Fellows Resigned (15).

J. A. Beaumont, Esq.
A. Brogden, Esq.
F. Derry, Esq.
O. R. Fabian, Esq.
Dr. J. S. Holden.
H. Lainson, Esq.
A. Macdonald, Esq.
Lieut.-Col. W. H. Mackesy.
G. A. Mosse, Esq.
C. O. Groom Napier, Esq.
J. N. Shoolbred, Esq.
Capt. H. Thurburn.
Rev. A. Underhill.
Rev. B. Waugh.
H. Wilson, Esq.

Fellows Removed (3).

J. S. Leigh, Esq.
J. J. Lundy, Esq.
W. Salter, 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 1879.

Professor Bernhard von Cotta of Freiberg.
Dr. F. V. Hayden of Washington.
Major-General F. von Kokscharow of St. Petersburg.
M. Jules Marcou of Salins.
Dr. J. J. S. Steenstrup of Copenhagen.

The following Personages were elected Foreign Correspondents during the year 1879.

Professor P. J. van Beneden of Louvain.
M. Édouard Dupont of Brussels.
Professor Guglielmo Guiscardi of Naples.
Professor Franz Ritter von Kobell of Munich.
Professor Gerhard vom Rath of Bonn.
Dr. Émile Sauvage of Paris.

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 H. C. Sorby, Esq., retiring from the office of President.

That the thanks of the Society be given to Prof. P. M. Duncan and Prof. J. Prestwich, retiring from the office of Vice-President.

That the thanks of the Society be given to H. Bauerman, Esq., Prof. P. M. Duncan, R. W. Mylne, Esq., Admiral Spratt, and Rev. T. Wiltshire, 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.

Sir P. de M. Grey-Egerton, Bart., M.P., F.R.S.
J. Evans, D.C.L., LL.D., F.R.S.
J. W. Hulke, Esq., F.R.S.
Prof. A. C. Ramsay, 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.

Rev. J. F. Blake, M.A.
Prof. T. G. Bonney, M.A., F.R.S.
W. Carruthers, Esq., 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.
J. C. Hawkshaw, Esq., M.A.
H. Hicks, M.D.
W. H. Hudleston, Esq., M.A.
Prof. T. McKenny Hughes, M.A.
J. W. Hulke, Esq., F.R.S.
J. Gwyn Jeffreys, LL.D., F.R.S.
Prof. T. Rupert Jones, F.R.S.
Prof. J. W. Judd, F.R.S.
Prof. N. S. Maskelyne, M.A., F.R.S.
J. Morris, Esq., M.A.
J. A. Phillips, Esq.
Prof. J. Prestwich, M.A., F.R.S.
Prof. A. C. Ramsay, LL.D., F.R.S.
Prof. H. G. Seeley, F.R.S.
W. W. Smyth, Esq., M.A., F.R.S.
H. C. Sorby, LL.D., F.R.S.

LIST OF
THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1879.

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.*
1851. Professor Angelo Sismonda, *Turin.* (*Deceased.*)
1853. Count Alexander von Keyserling, *Raykull, 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.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Alphonse Favre, *Geneva.*
1874. Professor B. Gastaldi, *Turin.* (*Deceased.*)
1874. Professor E. Hébert, *Paris.*
1874. Professor Édouard Desor, *Neuchâtel.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Paul Gervais, *Paris.* (*Deceased.*)
1875. Professor Fridolin Sandberger, *Würzburg.*
1875. Professor Theodor Kjerulf, *Christiania.*
1875. Professor F. August Quenstedt, *Tübingen.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. J. F. Brandt, *St. Petersburg.* (*Deceased.*)
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. Professor Bernhard von Cotta, *Freiberg.* (*Deceased.*)
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.*

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1879.

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.*
1864. Dr. Charles Martins, *Montpellier.*
1866. Professor J. P. Lesley, *Philadelphia.*
1866. Professor Victor Raulin, *Bordeaux.*
1866. Baron Achille de Zigno, *Padua.*
1869. Professor A. E. Nordenskiöld, *Stockholm.*
1869. Professor F. Zirkel, *Leipzig.*
1870. Professor Joseph Szabó, *Pesth.*
1870. Professor Otto Torell, *Lund.*
1871. Professor G. Dewalque, *Liége.*
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.*
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.*

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.

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.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS 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.*

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.

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.

Valuation of the Society's Property; 31*st December*, 1879.

Property.	£	s.	d.	£	s.	d.
Due from Longman & Co., for sale of Journals				60	17	8
Due from Stanford for sale of Map				3	11	10
Balance in Bankers' hands, 31 Dec. 1879				14	4	1
Balance in Clerk's hands, 31 Dec. 1879				1	11	8
Funded Property :—						
Consols, at 98	7050	0	0	6909	0	0
Reduced 3 per Cents. at 98	1036	5	5	1015	10	11
Arrears of Admission-fees (considered good)				88	4	0
Arrears of Annual Contributions (considered good)				194	8	0
				£8287	8	2

Debts.	£	s.	d.
Debts incurred previously to 31st December and now payable	90	19	0
Balance in favour of the Society	8196	9	2
	£8287	8	2

[*N.B. The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]

J. GWYN JEFFREYS, *Treas.*

4 *Feb.* 1880.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions for Quarterly Journal	3	5	4			
Due for Arrears of Annual Contributions	194	8	0			
Due for Arrears of Admission-fees..................	88	4	0			
				285	17	4
Estimated Ordinary Income for 1880:—						
Annual Contributions from Resident Fellows, and Non-residents of 1859 to 1861				1308	6	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				237	10	8
Advertisements in Quarterly Journal				7	10	0
Sale of Stock for Library Catalogue				220	0	0
Sale of Transactions, Library-catalogues, Ormerod's Index, and Hochstetter's New Zealand...	5	0	0			
Sale of Quarterly Journal, including Longman's account	210	0	0			
Sale of Geological Map, including Stanford's account	15	0	0			
				230	0	0
Balance against the Society..........................				99	17	10
				£2895	3	10

J. GWYN JEFFREYS, TREAS.

4 *Feb.* 1880.

the Year 1880.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes and Insurance	30	5	10			
Furniture	15	0	0			
House-repairs	40	0	0			
Fuel	30	0	0			
Light	30	0	0			
Miscellaneous House-expenses	125	0	0			
Stationery	25	0	0			
Miscellaneous Printing	60	0	0			
Tea for Meetings	21	0	0			
				376	5	10
Salaries and Wages:						
Assistant Secretary (five quarters)	437	10	0			
Clerk	140	0	0			
Assistants in Library and Museum	165	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Occasional Attendants	8	0	0			
Accountant	8	8	0			
				903	18	0
Library				140	0	0
Museum				5	0	0
Miscellaneous Expenditure, including postages				60	0	0
Diagrams at Meetings				10	0	0
Library Catalogue				220	0	0
Publications:						
Quarterly Journal (£1000) and postage £80)	1080	0	0			
Abstracts	100	0	0			
				1180	0	0
				£2895	3	10

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers', 1 January 1879	67	6	10			
Balance in Clerk's hands, 1 January 1879 .	9	6	6			
				76	13	4
Compositions				241	10	0
Arrears of Admission-fees	31	10	0			
Admission-fees, 1879	252	0	0			
				283	10	0
Arrears of Annual Contributions				121	6	6
Annual Contributions for 1879, viz. :—						
Resident Fellows £1262 2 0						
Non-Resident Fellows ... 25 4 0						
				1287	6	0
Annual Contributions in advance..................				12	12	0
Journal-Subscriptions in advance..................				0	16	4
Dividends on Consols	207	1	10			
,, Reduced 3 per Cents.......	30	8	10			
				237	10	8
Taylor & Francis: Advertisements in Journal, Vol. 34..				5	19	0
Bequest by the late Sydney Ellis, Esq.				1000	0	0
Publications:						
Sale of Journal, Vols. 1–34	140	0	9			
,, Vol. 35*	118	3	8			
Sale of Transactions......................	2	11	9			
Sale of Geological Map	12	7	10			
Sale of Ormerod's Index	2	6	7			
Sale of Hochstetter's New Zealand	0	4	0			
				275	14	7
*Due from Messrs. Longman, in addition to the above, on Journal, Vol. 35, &c.	60	17	8			
Due from Stanford on account of Geological Map ..	3	11	10			
	£64	9	6			
				£3542	18	5

We have compared the Books and Accounts presented to us with this statement, and we find them to agree.

(Signed) JOHN EVANS, W. H. HUDLESTON, } *Auditors.*

31 *Jan.* 1880.

Year ending 31 *December*, 1879.

EXPENDITURE.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes	18	5	10			
Fire-insurance	12	0	0			
Furniture	4	6	0			
House-repairs	24	5	5			
Fuel	42	17	9			
Light	26	3	6			
Miscellaneous House-expenses	124	18	7			
Stationery	24	16	10			
Miscellaneous Printing	56	0	3			
Tea at Meetings	21	0	0			
				354	14	2
Salaries and Wages:						
Assistant Secretary (three quarters)	262	10	0			
Clerk	140	0	0			
Library and Museum Assistants	165	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Occasional Attendants	8	0	0			
Accountants	7	7	0			
				727	17	0
Library				137	10	4
Miscellaneous Expenses, including postages				60	12	9
Diagrams at Meetings				4	1	6
Investment in £1036 5*s*. 5*d*. Reduced 3 per Cents.				1000	0	0
Publications:						
Geological Map	0	8	0			
Journal, Vols. 1–34	12	9	5			
,, Vol. 35	1131	19				
Abstracts	97	10	0			
				1242	6	1
Balance in Bankers' hands, 31 Dec. 1879	14	4	1			
Balance in Clerk's hands, 31 Dec. 1879	1	11	8			
				15	15	9
				£3542	18	5

"Wollaston Donation Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1879	31	19	7	Cost of striking Gold Medal awarded to Prof. B. Studer	10	10	0
Dividends on the Fund invested in Reduced 3 per Cents.	31	16	10	Award to Mr. S. Allport	21	9	7
				Balance at Bankers', 31 Dec. 1879	31	16	10
	£63	16	5		£63	16	5

"Murchison Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1879	19	13	4	Award to Prof. F. M'Coy, with Medal	10	10	0
Dividends on the Fund invested in London and North Western Railway 4 per cent. Debenture Stock	39	3	4	,, Mr. J. W. Kirkby	28	15	0
				Balance at Bankers', 31 Dec. 1879	19	11	8
	£58	16	8		£58	16	8

"Lyell Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1879	51	16	5	Award to Prof. E. Hébert, with Medal	23	2	0
Dividends on the Fund invested in Metropolitan 3½ per cent. Stock	68	18	0	,, Prof. H. A. Nicholson	22	19	5
				,, Dr. Henry Woodward	22	19	6
				Balance at Bankers', 31 Dec. 1879	51	13	6
	£120	14	5		£120	14	5

"Barlow-Jameson Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1879	24	12	7	Balance at Bankers', 31 Dec. 1879	39	6	5
Dividends on the Fund, invested in Consols	14	13	10				
	£39	6	5				

"Bigsby Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1879	6	3	6	Part cost of striking Gold Medal awarded to Prof. E. D. Cope	6	3	6
Dividends on the Fund invested in New 3 per Cents	6	3	0	Balance at Bankers', 31 Dec. 1879	6	3	0
	£12	6	6		£12	6	6

Award of the Wollaston Medal.

The Reports of the Council and of the Committees having been read, the President, Henry Clifton Sorby, Esq., LL.D., F.R.S., presented the Wollaston Gold Medal to Mr. H. Bauerman for transmission to Prof. A. Daubrée, F.M.G.S., and addressed him as follows:—

Mr. Bauerman,—

The Council has awarded the Wollaston Medal to Professor A. Daubrée, of Paris, in recognition of his long and arduous work in geology, and especially for his researches on the formation of minerals and on the metamorphism of rocks. We must all regret that his pressing duties as President of the French Academy prevent his being amongst us to-day, which otherwise, he informs us, would have given him much pleasure. You will kindly transmit the Medal to him, and assure him how highly we value his numerous contributions to physical geology. Possibly no one of our members more highly appreciates his labours than I do myself, since they have been so intimately connected with my own researches, though carried on in many cases in a very different manner. I would more especially allude to the great value of the experiments in which he was able to produce several very important minerals by the action of water at a high temperature; his researches on the formation of well-known Zeolites in the old Roman brick-work at Plombières; and numerous other applications of the experimental method to the solution of other important questions connected with various branches of physical geology. These have culminated in his recent and most valuable work on experimental geology—a work which ought to be the means, as, I trust, it will be, of introducing and still further extending the experimental method of inquiry into all branches of our science.

Mr. Bauerman, in reply, said that the regrets expressed by the President at the absence of the Wollaston Medallist would be shared by every one in the room. M. Daubrée had hoped to be present, and it was only within the last few days that he found that official duties connected with the Presidency of the Academy of Sciences prevented his being absent from Paris at this time. He held in his hand a letter in which M. Daubrée desired to testify his gratitude to the Society not only for the honour done to him on this occasion, but also for the previous award of the Wollaston Fund in 1861, and more particularly for the kindly interest expressed by our Presidents the late Sir Roderick Murchison and Mr. Leonard Horner in the course of experimental researches then recently commenced, which had been a powerful encouragement to him in following out that particular line of work; and he was the more anxious to record this as these distinguished leaders of our science were no longer with us.

Award of the Murchison Medal and Fund.

The President next handed the Murchison Medal and the proceeds of the Murchison Donation Fund to Mr. R. Etheridge, F.R.S., F.G.S., and addressed him as follows:—

Mr. Etheridge,—

In this room and before this assembly it is hardly necessary for me, in presenting you with the Murchison Medal, to enter into any explanations of the reasons which have induced the Council to award it to you. Your published writings, the greater part of which have appeared in our 'Quarterly Journal,' and must be well known and highly appreciated by most of us here present, would alone suffice to justify the Council in their award. But when we take into consideration your long-continued palæontological work in connexion with the Museum of the Geological Survey, the results of which have silently exerted so great an influence upon the progress of geology in this country, your constant help to others in their investigations, and your labours as a teacher in connexion with the School of Mines, which must have brought forth much good fruit, I think every one will acknowledge that you are fully entitled to all the honours which the Geological Society can confer upon you. I must refer especially to the valuable Catalogue of British Fossils upon which you have so long been engaged, to assist you in the completion of which the Council have joined to the award of the Murchison Medal the whole proceeds of the Fund for the present year.

Mr. Etheridge, in reply, said:—

Mr. President,—

This is the second time the Council of the Geological Society has conferred upon me the honour of being one of its recipients. In 1871 I was presented with the balance of the Wollaston Fund; and to-day I receive, at your hands, evidence of the marked distinction and approbation of the Society in being selected to receive both the Murchison Medal and Fund. I am indeed gratified at being its present recipient. Sir Roderick Murchison was for fifteen years my esteemed chief and valued friend; I therefore attach especial value to this mark of your approbation of any labour that I have done in the cause of that science for which the Medal was founded. To me no labour in the field of natural science is too great to be devoted to carrying out those duties I have to perform; and the reward bestowed upon me to-day I hope still to merit and repay, through work yet to be done for our Society, and by aiding others to spread abroad the truths of nature as taught through geological and palæontological research.

Award of the Lyell Medal.

The President then presented the Lyell Medal to Mr. John Evans, D.C.L., LL.D., F.R.S., F.G.S., and addressed him as follows:—

Dr. Evans,—

The Council has awarded to you the Lyell Medal and the sum of twenty guineas from the proceeds of the fund, in recognition of your distinguished services to geological science, especially in the department of post-tertiary geology. I can well remember the time when there appeared to be an almost impassable gulf between antiquarians and geologists; but you and your fellow workers have so completely bridged over that gulf, that we now can scarcely say where archæology ends and geology begins, nor whether to rank and value you most as an antiquary or a geologist. Your long-continued labours and valuable writings on flint implements have equally advanced both the sciences to which I have alluded, and thrown great light on that most interesting problem—the antiquity of man. As another claim on our highest regard, I would refer to the great services you have rendered to this Society in every possible way that could advance its interests and that of our science. We feel assured that the founder of this Medal would have heartily approved of the award, since your researches have been so intimately connected with those subjects which in his later years attracted so much of his attention.

Dr. Evans in reply, said:—

Mr. President,—

It is with much gratification that I receive this award at your hands, for I regard it not only as a kindly mark of appreciation on the part of yourself and the Council, but also as a memorial of my old and valued friend and master Sir Charles Lyell. This Medal has, indeed, a peculiar interest to me in connexion with him; for it was while I was one of your Secretaries that he did me the honour of consulting me as to the foundation of this fund; and, subsequently, it was as your President that I had the satisfaction of handing the first Lyell Medal and the first proceeds of the Fund to no less distinguished a geologist and palæontologist than Prof. Morris. I am highly flattered to find myself associated with him and other eminent geologists in the list of the recipients of this Medal, and only wish that I was equally deserving of the honour. What little I may have done, either directly or indirectly, to promote the advance of geological knowledge, has been mainly the result of my now somewhat long connexion with this Society, and the many valuable and, I hope, enduring friendships with its Fellows that I have thus been enabled to make. This connexion is one upon which I look back with unalloyed satisfaction, and of which this Medal will always preserve the record.

Award of the Wollaston Donation-fund.

The President next presented the balance of the proceeds of the Wollaston Donation Fund to Mr. Thomas Davies, F.G.S., and addressed him as follows:—

Mr. Davies,—

The Council of this Society has awarded to you the balance of the proceeds of the Wollaston Fund, as a testimony of the value of your researches in mineralogy and lithology, and to assist you in the further examination of the microscopic structure of rocks. I need hardly say how much this subject claims my own sympathy, and we feel assured that it would also have secured that of the founder of the fund. I am astonished at the rapid growth of this branch of inquiry since, some thirty years ago, I with my own hands prepared the first thin sections of rocks for geological purposes. Very much, however, remains to be learned; and we hope that the award of the Council will enable you to still further extend your inquiries. Valuable as have been the results which you have made public, we all feel that in many cases you have still further advanced our science by the generous assistance which you have afforded to others. As a slight token of our regard, we beg you will accept the usual balance of the Wollaston Fund, which I now present to you.

Mr. Davies replied:—

Mr. President,—

I am deeply sensible of the honour conferred upon me by the Council in making me this award, and I beg to tender them my sincere thanks.

That branch of the science of mineralogy which embraces the habits, associations, and modes of occurrence of mineral species has long been of special interest to me. The gratification derived from having been enabled to apply the knowledge I have gained in assisting others to elucidate the structure and probable origin of some of the older rocks, is now greatly enhanced by this recognition. I regard it also as an incentive to the continuance of this work, which now occupies so many scientific minds both at home and abroad.

Award of the Lyell Geological Fund.

In handing to Prof. Seeley, F.R.S., F.G.S., the balance of the proceeds of the Lyell Fund, for transmission to Prof. F. Quenstedt, F.M.G.S., the President said:—

Professor Seeley,—

It is with much pleasure that I hand to you the balance of the proceeds of the Lyell Donation Fund for transmission to Professor

Quenstedt, of Tübingen, to whom it has been awarded by the Council of the Society. Professor Quenstedt's labours in various departments of geology, extending over a period of more than five and forty years; his published writings, commencing with memoirs on mineralogical subjects in the year 1835, followed very shortly by others dealing with palæontological matters, culminating in his admirable Manuals of Palæontology and Mineralogy, published respectively in 1852 and 1854, and of which several later editions have appeared,—in his great work 'Der Jura,' on the Jurassic rocks of Southern Germany,—and in his magnificent 'Petrefactenkunde Deutschlands,' commenced in 1846, and still in progress; his renown as a successful teacher of geology and mineralogy; and his services to science by the establishment of the fine Museum over which he so worthily presides at Tübingen, have already been recognized by this Society in his election as a Foreign Correspondent in 1863, and as a Foreign Member in 1875. It is with the purpose of showing their continued appreciation of these labours, and especially to aid the distinguished Professor in the completion of his last-mentioned great work, that the Council have decided to award to him the balance of the Lyell Donation Fund; and in placing it in your hands I have to beg that you will request his acceptance of it in the spirit in which it is offered.

Professor Seeley, in reply, said,—

Mr. President,—

I am sure that Professor Quenstedt will gratefully appreciate the terms in which you have expressed, on behalf of the Geological Society, admiration for his great efforts to advance geological science. Upwards of seventy years of age, he is labouring with the energy of mature powers; but with unaffected modesty expresses to me astonishment that his work, which is still unfinished, should have been thought worthy of this award. The fact that the Fund is associated with the name of the great master Sir Charles Lyell gives it for him an additional value; for so far back as 1857 Sir Charles sent to Prof. Quenstedt his own clinometer, and in many ways in after years gave evidence of sympathy with the investigations of the distinguished teacher of Tübingen. I may say that in these days of division of labour one thinks with wonder of the variety of Prof. Quenstedt's work, signalized as it has been by success in every department. The perfection of his work may, perhaps, be summed up in the one word "thoroughness," for it begins with an almost unrivalled development of the treasures in his wonderful museum, and culminates in the rare courtesy and singleness of heart with which he communicates to others the treasures thus stored in his mind. I am sure he will gratefully accept this award in the spirit in which it is offered, and for the further advancement of science.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Henry Clifton Sorby, Esq., LL.D., F.R.S.

In accordance with the usual practice, I have to preface my address with some brief obituary notices of a few of those Fellows and Foreign Members whose loss has been announced to the Society in the course of the past year *.

James Nicol, F.R.S.E., F.G.S., &c., Professor of Natural History in the University of Aberdeen, was born in 1810, in the Manse of Traquair, near Inverleithen, Peeblesshire. His father, the Rev. James Nicol, the Minister of the parish, and widely known for his poetical writings, was a man of refined tastes, and enjoyed the friendship of the more prominent men in science and literature in his day, from Sir David Brewster to Wordsworth. On the death of his father in 1819, young Nicol removed with the family to the neighbouring village of Inverleithen. Here his early education was completed, partly in the parish school, partly in private, under the fostering care and guidance of the Rev. Mr. Pate, the Minister of the parish. The daily rambles of the young scholar amid the bold and picturesque scenery of his native district, led him early to study its geology, which at that time was wholly unknown. The absence of fossils and of intelligible sections among these old rocks, as contrasted with their great interest from the mineralogical and petrographical points of view, had their natural effect in directing his attention most especially to the mineralogical aspect of geology. The early bias thus originated was probably fixed for life by his subsequent attendance at the classes of Professor Jameson. He entered the University of Edinburgh in 1825; and after passing the Arts course, he attended the Divinity Hall. After completing his studies in Edinburgh, he crossed over to Germany and studied at the Universities of Berlin and Bonn, where he worked with the most famous mineralogists of his day. His studies, however, were not exclusively confined to natural science. He seems to have had a rare faculty for the acquisition of knowledge; and his acquaintance with the subject he studied was always exact and profound.

On the completion of his University studies, he returned to his native valley of the Tweed, and devoted himself to the unravelling of the more obscure problems of its geology. In 1841 he obtained the prize awarded by the Highland Society for an essay on the Geology of Peeblesshire, and subsequently a second for his essay on the Geology of the neighbouring county of Roxburghshire. In the first of these publications the presence of fossils in the lower Palæozoic rocks of the Inverleithen district was made known for the first time to the scientific world.

* In the preparation of these notices I have to acknowledge with thanks assistance received from Mr. H. Bauerman, Mr. C. Lapworth, Prof. Seeley, Dr. H. Woodward, and the Assistant Secretary.

The next few years were apparently spent by him in extended geological journeys throughout Scotland, more especially in its southern portions. The fruits of these investigations, as supplementary to those of his more immediate predecessors in this field, were given to the world in a work entitled 'A Guide to the Geology of Scotland.' This little book, which was very carefully illustrated by plates and a small map of Scotland, was a valuable production in its day, and bears upon every page the marks of the untiring energy and industry of its young author, and of his extended acquaintance with the geognosy of his native land.

In 1847 we find him appointed Assistant Secretary to the Geological Society of London. Here he edited the 'Quarterly Journal' of the Society, and gained the friendship of many of that illustrious group of British geologists which then assembled at its Meetings. In this congenial atmosphere Nicol's mineralogical studies were prosecuted with increased ardour; and in 1849 he published his well-known text-book of mineralogy, which even at the present day holds no mean place among our books of reference.

First among his geological friends stood Sir R. Murchison; and through his influence, with that of Sir H. De la Beche and Sir Charles Lyell, Nicol was appointed in 1849 to the post of Professor of Geology in Queen's College, Cork. In 1853 he relinquished the post for the more lucrative position of Professor of Natural History in the University of Aberdeen. This he retained till his death, which took place in 1879.

In spite of his predilection for mineralogy, it is beyond question that Nicol will be remembered among us here less for his mineralogical works than for his numerous and valuable memoirs upon the stratigraphy of Scotland. His papers upon the Geology of the Southern Uplands of Scotland are of especial interest and value. In 1848 he published in our Journal an elaborate memoir "On the Rocks of the Valley of the Tweed" (Quart. Journ. G. S. iv. p. 195), demonstrating their fossiliferous character, and giving the first general view of the entire succession among the transition-rocks of South Scotland, and applying to them for the first time the title of Silurian. This was succeeded in 1849 by a memoir "On the Silurian Rocks of the S.E. of Scotland" (Q. J. G. S. vol. vi. p. 53), in which for the first time Graptolites were figured from these ancient deposits. In 1850 he accompanied his friend Sir R. Murchison in a tour through the Southern Uplands, and aided him in his detailed investigation of the geology of the fossiliferous Girvan area. In 1852 he communicated a complete *résumé* of the results of his extended researches into the geological structure of the Southern Uplands, illustrating it by the first complete transverse section through the Silurian rocks from the Pentlands to the Cheviots. A reduced copy of this section has illustrated all the subsequent editions of Murchison's 'Siluria,' and stands substantially unmodified in the official publications on South-Scottish geology.

On his translation to the University of Aberdeen in 1853, Nicol transferred the sphere of his geological investigations to the metamorphic rocks of the Highlands, which he had as early as 1844 been the first to suggest were probably of the same geological age as those of the Southern Uplands. In 1855, in his paper "On the Sections of Metamorphic and Devonian Rocks of the Eastern Extremity of the Grampians" (Quart. Journ. vol. xi. p. 544), he proved the existence of a grand fault between the metamorphic rocks and the Old Red Sandstone of Kincardine and Forfar. The same year he visited the well-known Torridon and Durness area in the north-west Highlands in company with Sir R. Murchison, in order to verify Mr. Peach's discovery of fossils in the metamorphic limestone of that region. On his return he communicated an independent memoir to the Geological Society (Quart. Journ. vol. xiii. p. 17), in which he claims to have published for the first time what is now the generally accepted order of succession, viz.:—(*a*) Lower Gneiss; (*b*) Conglomerate and Red Sandstone; (*c*) Quartzite; (*d*) Limestone, overlain by (*e*) an Upper Gneiss. Arguing mainly from the petrographical character of these rocks, he threw out the suggestion that the Torridon Sandstone might be of Devonian age, and that the overlying limestone and gneiss might be of the age of the Lower Carboniferous. After Mr. Salter's demonstration that the fossils of the Durness Limestone were not Carboniferous, but belonging to the deepest zone of Murchison's Silurian, Nicol again visited the north-west Highlands. In a memoir giving the chief results of this expedition (Quart. Journ. Geol. Soc. xvii. p. 85) he retracted his former admission of an Upper Gneiss, superior to the Durness Limestone; and claimed to have proved that the line of demarcation between the Durness series and the eastern gneiss of Central Sutherlandshire is actually a line of fault, the Torridon and Durness strata always overlying or abutting against, but never dipping under, the eastern gneiss. These new opinions led to a keen controversy between himself and his old friend Sir R. Murchison; but after the publication of two additional memoirs on the subject in 1862 and 1863, in which he defended his view that the central gneiss of the Highlands is of the same general geological age as the Lewisian gneiss of the Outer Hebrides, and that the only metamorphic strata that can safely be called Silurian are the less-altered rocks upon the outer borders of the Highlands, he ceased to contribute papers to our Society upon the subject. A little work on the Geology and Scenery of the North of Scotland contains his last published words upon the controversy. He never ceased to wander, however, year after year, among these Highland rocks in search of fresh evidence in support of his view. Though he never published the results of these later investigations, he remained fully convinced of the correctness of his own view upon this question till the day of his death. His opinions upon the Highland succession were shared by a very few geologists in his day; but there is every probability that the whole question will soon be reopened by those who believe that an opinion held so long and so tenaciously by such a modest and patient investigator as Nicol is certain to have been founded upon solid grounds.

In addition to the papers already noticed, Nicol contributed memoirs to this Society upon the New Red Sandstone of the N.W. of Scotland (Quart. Journ. Geol. Soc. xiv. p. 167.), and upon the 'Parallel Roads of Glen Roy," which he contended were essentially marine in their origin.

In literary and scientific labour Nicol was indefatigable. The works we have referred to form but a small fraction of his multifarious publications. His Geological Map of Scotland, published n 1858, was in every respect the best in its day. In addition to the 'Manual of Mineralogy,' he published a smaller work, the 'Elements,' upon the same subject, which is now in its second edition; and it still forms the article "Mineralogy" in the 'Encyclopædia Britannica,' to which, as to many of the leading Magazines, he was a voluminous and valued contributor.

His sturdy frame and indomitable strength of will bore him unharmed through countless geological journeys that would have overtasked the majority of men. His genial companionable nature gained him the hearty love of his students and the undying affection of his many friends. Ever of singleness and purity of purpose, he disdained to swerve from what he felt to be the proper path, either in the interest of authority or expediency; but for those whom he could aid by his friendship or example, his patience was inexhaustible and his generosity unbounded.

Sir Walter Calverley Trevelyan, Bart., M.A., F.S.A., F.R.S.E., F.G.S., &c., of Nettlecombe, Somerset, and Wallington, Newcastle-on-Tyne, Northumberland, was the sixth Baronet of this line*, and born in 1797. He was educated at Harrow, and early displayed a love for Natural-history pursuits, especially Botany, his chosen school-fellow being the late Mr. Fox Talbot (afterwards the chief discoverer of photography). From Harrow Sir Walter went to University College, Oxford, where he eagerly attended the lectures of the Botanical and Geological Professors; and after taking his M.A. degree, he proceeded, in 1820, to Edinburgh to pursue further his scientific studies.

In 1817 he was elected a Fellow of this Society, and in 1827 he read his first paper:—

(1) "On a Whin-dyke in Cooper Colliery near Blithe, Northumberland" (Trans. Geol. Soc. 1829, vol. ii. pp. 405, 406; Proc. Geol. Soc. 1834, vol. i. p. 23).

His subsequent communications to this Society were as follows:—

(2) "Indications of recent Elevations in the Islands of Guernsey and Jersey, and on the Coast of Jutland, and on some Tertiary Beds near Porto d'Anzio" (Proc. Geol. Soc. vol. ii. 1838, pp. 577, 578).

(3) "On Fractured Boulders found at Auchmithie near Arbroath" (Quart. Journ. Geol. Soc. 1845, pp. 147, 148).

(4) "On Scratched Surfaces of Rock near Mount Parnassus" (Proc. Geol. Soc. 1846, vol. iv. p. 203).

* Trevelyan of Nettlecombe, Somerset. Creation 1661.

In 1821 he visited the Faroe Islands, and resided there for some time, making numerous observations on their vegetation and temperature. Seventeen out of the twenty-two islands were inhabited at that date. (See his published account in 'Jameson's Edinburgh New Philosophical Journal,' for 1835, vol. xviii., printed in 4to for private circulation in 1837).

Between 1835 and 1846 he travelled much in the south of Europe, and made observations on the Tertiary Geology of the Italian Peninsula, and upon the tides in the Mediterranean.

He succeeded to the title on the 23rd May, 1846, together with the fine landed estates belonging to his family in Northumberland, Somersetshire, Devonshire, and Cornwall; and during the thirty-three years in which he held the title and property, he made very extensive improvements, thus permanently increasing the value of his inheritance. He made the farmhouses and cottages on his estates models of what such dwellings should be. He also did much towards improving the breed of shorthorn cattle, of which Sir Walter possessed an extensive herd.

He was not only an accomplished botanist and geologist, but he was also an excellent authority on antiquarian and topographical subjects, and liberally supported all projects for the increase and development of knowledge.

Of the three interesting volumes of 'Trevelyan Papers' published by the Camden Society, the last was edited by Sir Walter in conjunction with his cousin Sir Charles Trevelyan, Bart. (who succeeds to the family estates).

For a long period he maintained an extensive correspondence with a wide circle of literary and scientific men, both at home and abroad, and was an ardent collector of both scientific books and specimens.

Sir Walter Trevelyan's Museum at Wallington contained a good series of British and Italian fossils, valuable collections of minerals and recent shells, a good series of Ethnological specimens, together with a general Natural-History collection of objects, most of which he had himself obtained during his travels.

To the British Museum, the Museum of Practical Geology, the South-Kensington Museum, the Museums of Oxford, Kew, Edinburgh, Newcastle-upon-Tyne, the Royal Geographical Society, the Society of Antiquaries, London and Scotland, and many other societies and institutions Sir Walter Trevelyan was a munificent benefactor.

He took the most lively interest in the improvement and advancement of the New Museum of the University of Oxford, towards the cost of which he also liberally contributed.

He died at Wallington, Northumberland, on March 23, 1879, in his eighty-second year.

John Waterhouse, F.R.S., F.R.A.S., F.G.S., &c., was born at Halifax, Yorkshire, on the 3rd of August, 1806. His father, John Waterhouse, of Well Head, was the representative of a family which for 400 years had been intimately connected with the prosperity of the town and neighbourhood.

Very early in life he evinced a decided taste for scientific studies; and the training which he received at school only served to increase this preference, and enabled him to obtain a sufficient knowledge of mathematical science, which he turned to good account in after years in the various branches of physical research to which he gave attention. A certain weakness of constitution which prevented him in his youth from great physical exertion, only seemed to stimulate his mental activity; and when, in search of change of climate with a view to invigorate his health, he undertook a voyage round the world, the training which he had received and the bent of his mind enabled him to record his observations in a journal which is a storehouse of scientific facts and notices, and which, had his modesty not shrunk from having it printed, would have proved the record of a "Scientific Expedition" when such journeys were far less numerous than at present, and attended by far greater inconveniences. During this voyage, his love of nature and the wide range of his scientific tastes acquired an increased stimulus; and when he returned home his experience in observation and his knowledge of natural phenomena in different parts of the world enabled him to enter with renewed pleasure into the less active study of the physico-mathematical sciences.

He established an astronomical and meteorological observatory, and in connexion with the latter published a few years ago a complete work on the Meteorology of Halifax; which will continue to be a model for all such local observations.

Practical botany also engaged his attention; and his gardens were distinguished throughout the neighbourhood for the rich variety of their contents, especially in rare plants and exotics, of which he was justly proud.

His favourite studies were astronomy, geology, electricity, and light; and in connexion with the latter he was identified with the early progress of photography, and with the discovery by the Rev. J. B. Reade, F.R.S., of the method of taking portraits first upon leather, and afterwards upon paper, instead of silver plates or glass, and also with the chemical means of giving permanence to such images.

He was specially interested in the progress of microscopy, and was himself both a skilful observer and an adept at those manipulations which are necessary in the preparation of objects for examination. He was also extremely fond of music, and was a skilful performer on the violoncello. Indeed he seemed able to turn his hands to any pursuit; and such was the aptitude which he possessed for grasping the general principles upon which any practical operation depended, that he speedily was enabled to do with proficiency work which required, under ordinary circumstances, years of patient labour and practice.

As might be expected, he was also identified with those movements which had for their object the spread of scientific knowledge, and, in connexion with the local Literary and Philosophical Society (of which he was one of the founders and for many years President), lectured on more than one occasion on various scientific subjects, as as well as enriched the Museum with many choice objects of natural history collected during his travels.

He was also connected with the Mechanics' Institute during its early years, and was active as a magistrate, being for many years Chairman of the County Bench at Halifax, and a Deputy Lieutenant for the West Riding.

In later years a stroke of paralysis, which compelled his retirement into private life, only made him appreciate more his beautiful gardens, until a severer form of his malady prevented all mental pursuits, and finally terminated his life on the 13th of February, 1879, in the 72nd year of his age.

He was a Fellow of the Royal Society, of the Royal Astronomical Society, of the Royal Microscopical Society, of the Geological Society, and several others; and although a certain timidity of disposition prevented him from making original discoveries, few men were better acquainted with the whole range of scientific inquiry; and his kind and generous disposition, as well as the means at his command, enabled him to liberally assist many who were pursuing the difficult path of original investigation.

David Page, LL.D., one of the most voluminous writers of our day of popular and educational books on geology, was born on the 24th August, 1814, at Lochgelly, in Fifeshire, where his father carried on business as a stonemason, builder, and contractor. He received his education at the parochial school; but at the early age of fourteen he was sent to the University of St. Andrews, where it was intended that he should study for the ministry of the Church of Scotland. Among the students at St. Andrews at the same time were the brothers Harry and John Goodsir and Dr. Lyon Playfair. In the ordinary subjects of instruction David Page made considerable progress, and, indeed, his proficiency was rewarded by several college prizes and honours; but the special bent of his mind was so decidedly towards the study of the natural sciences, especially geology, that, after taking the opinion of his friends, he decided to devote himself to a scientific and literary career. So early as 1834 (the year in which he left St. Andrews) he published an essay on the Geology of Fife and Kinross; but for some years afterwards his labours were probably confined to lectures and anonymous writings, as, with the exception of a volume of poems (published in 1838), we do not find his name attached to any works until after his connexion with Messrs. Chambers had commenced. This was in 1843, when David Page was engaged to act as confidential literary and business adviser to those enterprising publishers; and during his connexion with them, which lasted till 1851, his influence was felt in the production of those scientific text-books and other articles issued by the firm, which undoubtedly produced a considerable diffusion of scientific knowledge. His earliest work published after he had entered the service of Messrs. Chambers, appeared in 1844, under the title of 'Rudiments of Geology;' and from that time till the close of his life it was succeeded by an uninterrupted flow of new books and new editions treating of geology and the collateral sciences from various points of view.

Professor Page became a Fellow of this Society in 1853. He was also a Fellow or Member of various Geological and other learned Societies, and in 1863 was President of the newly reestablished Geological Society of Edinburgh. In 1867 the University of St. Andrews conferred upon him the honorary degree of Doctor of Laws. Finally, in July 1871, he was appointed Professor of Geology and Mineralogy in Durham University College of Physical Science, a position which he retained to the time of his death, which took place at Newcastle on the 9th March 1879.

Besides the numerous educational and popular works already alluded to, Professor Page read several papers, chiefly relating to Scottish Geology, at the Meetings of the British Association and before the Physical Society of Edinburgh and the Edinburgh and Glasgow Geological Societies. He never contributed to our 'Proceedings.'

Prof. Page's great merit was that of being one of the earliest, and throughout his life one of the most successful, popularizers of geological ideas. In the preparation of text-books, and handbooks for more or less advanced students, and of lighter articles for those who can hardly yet be called students, and in the delivery of popular lectures, he was incessantly active, notwithstanding long-continued ill health; and in these ways, as also by the zealous discharge of his duties in the College of Physical Science at Newcastle, he no doubt contributed greatly to the general diffusion of geological knowledge. In private also his geniality of character and enthusiasm gave him considerable influence over the minds of those with whom he was brought into contact.

Carl Bernhard von Cotta was born at Zillbach, near Eisenach, in Thüringen, on the 24th of October, 1808, and studied first at the Mining Academy of Freiberg, where he matriculated in 1827–31, and subsequently at the University of Heidelberg, taking the degree of Doctor of Philosophy. From 1839 to 1842 he formed part of the teaching staff and was Secretary of the Academy for Forestry and Agricultural Science at Tharand, near Dresden, of which his father was the founder and first Director. This association led him at first to the study of vegetable palæontology—his earliest work, that on Dendrolites (or fossilized tree-stems), which appeared in 1832, being founded upon the large collection of fossil plants in his father's possession at Tharand; but the greater attractions presented by the strata in the immediate neighbourhood and in the adjacent Elbe valley led him to devote himself to field-geology, which thenceforward became a principal work of his life.

The first place among his numerous published works must undoubtedly be given to his geological maps. The idea of a general

Geological Map of Saxony was entertained as early as 1780; and during Werner's lifetime a commencement was made by dividing the country into 90 districts, which were allotted for examination among the different mining-officials and other competent observers. In 1830 the revision and reduction of these preliminary observations was confided to C. F. Naumann, then Professor of Geology at Freiberg, with a view to their publication upon the large military map of Saxony on the scale of $\frac{1}{120000}$ (rather more than half an inch to a mile); and in a short time Cotta became associated with him in the work. Owing to the great cost, however, only the more interesting portions, containing the kingdom of Saxony proper, were published, between 1836 and 1844. These form twelve sheets in a connected block, the numeration, however, being that of the larger military map. The last of these was published in 1843; but some of the sheets have been revised and issued at later dates. In addition to a short pamphlet, a detailed description was drawn up for each sheet; but only five of these appear to have been published: the first two were written by Naumann, the third by Naumann and Cotta, and the remainder by Cotta alone.

Subsequently the Survey was extended to the Thuringian country, the map (forming four sheets on the same scale) being published by Cotta alone in 1845–1847. These maps may be considered as the first exact and systematic national surveys made on the continent of Europe; and they are remarkable for the large amount of exact detail given, on what is now regarded as a comparatively small scale—seventy different colours and signs being employed in their construction. The improvement of geological cartography was to the last a favourite subject with this author; and by one of his latest official acts, urging upon the Government the necessity of larger and more detailed maps, he was a powerful instrument in the initiation of the new survey on the scale of $\frac{1}{25000}$, uniform with that of Prussia, which is now being carried out under the direction of Dr. Credner.

In 1842, on the translation of Naumann to the University of Leipzig, Cotta succeeded him as Professor of Geology at Freiberg, adding to his geological lectures in the following year a course on Palæontology, and in 1851 another on the special phenomena of mineral deposits (Erzlagerstättenlehre), which three subjects he taught continuously until his retirement in 1874. From his frank and genial manner he was always a great favourite with his students, his classes being well attended: but he was even more successful as a demonstrator in the field; and his excursions were always extremely popular, even with those students who were not immediately connected with his classes.

In addition to works descriptive of geological maps, Cotta was a very industrious writer of text-books, biographical memoirs, and popular works on geology, the total number of his memoirs and other publications amounting to about eighty. Among the first the more important are his 'Gesteinslehre' and 'Lehre von den Erzlagerstätten'—the former a treatise on rocks, which appeared in 1855, a second edition in 1862, and an English translation by Mr. P. H. Lawrence, with additions by the author, in 1866. This is interesting as being the last systematic work on the subject that appeared before the general application of microscopic mineralogy to the study of rocks. The treatise on mineral deposits was issued as a text-book for his Freiberg class in 1854, the author having commenced, in 1847, a miscellany under the title of 'Gangstudien' (Lode studies), containing monographs on mineral veins in different countries, contributed by himself and others, which was continued at irregular intervals up to a fourth volume in 1862. In 1859 the text-book was reprinted in an extended form in two volumes; and in 1861 it was rearranged under the title of the 'Mineral Deposits of Europe.' An English translation, under the title of 'A Treatise on Ore Deposits,' by Mr. F. Prime, was published in America in 1870.

Subsequently to 1845 mineral veins formed a chief object of his study, his attention being principally devoted to the mining-districts of the Eastern Alps, Hungary, the Banat, and the Bukowina, special memoirs upon which were published from time to time. In 1868, on the invitation of the Emperor of Russia, he made a summer trip to the Altai, the result of his observations being published in a large octavo volume in 1871.

Cotta's popular and general geological works have attained a circulation in Germany comparable with those of Sir Charles Lyell in this country. The more important among these are:—1. 'Geological Letters upon Humboldt's Kosmos,' 1848, with a third edition in 1855; 2. 'Geological Pictures,' a collection of articles originally contributed to the Illustrirte Zeitung of Leipzig, of which six editions appeared between 1852 and 1876, and a Russian translation in 1859; and 3. 'Modern Geology' (Geologie der Gegenwart), in which he sought to establish the principle of development applied by Darwin to the origin of species as the general law of terrestrial development, published in 1866, and, in a fourth edition, in 1874, besides translations into Magyar and Russian. The same idea of continuous development as a factor in geology appears in an earlier work, 'Deutschlands Boden,' in which the influence of soil and geological structure upon the population of Germany is treated at length. This appeared in 1854, and, in a second edition, in 1858.

In 1857–58 he revised and supplied a preface to a translation of the 5th edition of Sir Charles Lyell's 'Geology.'

His latest work was a commencement of a general history of Geology; the first volume (under the title of 'Geologisches Repertorium'), containing the titles of the principal works on Geology published between 1546 and 1876, appeared in 1877.

He was elected a Foreign Correspondent of this Society in 1867, and a Foreign Member only last year. After his retirement he resided at Freiberg until his death on September 15, 1879.

Among the Foreign Members of which our Society has to deplore the loss, one of the most distinguished is

François Louis Paul Gervais, whose numerous and valuable writings must be familiar to all students of palæontology. He was born in Paris on the 24th September, 1816; and as early as the year 1835 he became assistant to De Blainville (who occupied the Chair of Comparative Anatomy at the Paris Museum), and remained associated with that great naturalist until 1845, when he was appointed Professor of Zoology and Comparative Anatomy to the Faculty of Sciences of Montpellier. In 1865 Gervais was appointed Professor at the Faculty of Sciences of Paris, and in 1868 Professor of Comparative Anatomy at the Museum, a position which he held until his death on the 10th February, 1879. He was a Doctor of Sciences and of Medicine, a correspondent of the Institute of France (since 1861), and a corresponding member of many Societies. He was one of the earliest Foreign Correspondents of this Society (1863), and was elected a Foreign Member in 1875.

During his early association with De Blainville, Gervais assisted him in the preparation of his great work, the 'Ostéographie;' but the bent of his mind at this time appears to have been towards the study of those groups of animals included by Linnæus in his order "Insecta Aptera," and especially of the Myriopoda, upon which he began to write as early as the year 1835. He was, in consequence, selected to complete and supplement the great work on the Aptera (Spiders, Scorpions, Myriopoda, and true apterous Insects) commenced by Baron Walckenaer in the 'Suites à Buffon,' of which he wrote the third and fourth volumes, published in 1844 and 1847.

In numerous memoirs published in various periodicals, and in the natural-history appendices to voyages, Professor Gervais treated of animals belonging to nearly all the principal groups, and he also published 'Eléments de Zoologie' in 1866 (of which a second edition appeared in 1871), and, in conjunction with Van Beneden, a 'Zoologie Médicale' in 1859. During the whole of this period, however, his attention was being more and more directed towards the vertebrata, recent and fossil, especially the Mammalia; and it is mainly upon his researches on the latter that his fame as a palæontologist will rest. In 1854 and 1855 he produced his 'Histoire Naturelle des Mammifères,' in two large 8vo volumes, giving an excellent semipopular description of the structure and habits of the recent Mammalia, with references to all the fossil forms of which any thing definite was at that time known. In his 'Zoologie et Paléontologie Françaises,' published in two 4to volumes between 1848 and 1852, and of which a second edition appeared in 1859, the Mammalia occupy by far the largest share of the space; and this is also the case with the 'Zoologie et Paléontologie générales,' although in both these books fossil birds and reptiles receive more or less of the author's attention. In the last-mentioned work we find important researches upon the fossil mammals of South America, to which Professor Gervais had already devoted a special memoir, under the title of 'Recherches sur les Mammifères fossiles de l'Amérique méridionale,' published in 1855. By these great works, and numerous smaller memoirs published in various periodicals and read before learned Societies, Prof. Gervais has contributed most importantly to the advancement of our knowledge of the Tertiary Mammalia.

One of the memoirs in the 'Zoologie et Paléontologie générales,' is devoted to the discussion of the antiquity of man, and of the changes which have taken place in the European fauna since the close of the Tertiary period—subjects which attracted much of the author's attention during the last twenty years of his life.

Johann Friedrich Brandt was born May 25, 1802, at Jüterbogh, in the Prussian province of Brandenburg, and died at the Baths of Merreküll, on the Gulf of Finland, 15th July, 1879. He was carefully educated by his parents at Jüterbogh, where his father was a successful surgeon; and here he derived from his uncle Hensius the love of botany which engrossed much of his attention for twenty years. From the Gymnasium of Jüterbogh he passed to the Lyceum of Wittenberg, studying classics, and in 1821 entered the University of Berlin. In his first vacation he visited the Harz with his fellow-student Ratzeburg, and, having won the medical prize for an essay on Respiration, was enabled next year to travel through the Riesengebirge. Subsequently he made many journeys with Göppert, who remained his friend throughout life. Lichtenstein's lectures in Berlin stimulated him to active zoological work, and led him to visit museums of anatomy. He at this time acted as amanuensis to Rudolphi. In 1825 he published a 'Flora Berolinensis.' His examinations were passed with distinction in 1826; and he became M.D., surgeon, and accoucheur. His inaugural thesis was entitled 'Observationes Anatomicæ de Mammalium quorundam vocis instrumento.' The year following he became assistant to Heine, and for nine months was engaged in the Zoological Museum. In conjunction with Ratzeburg he began in 1827 to issue the first volume of their 'Medical Zoology,' which occupied the next two years; and he also wrote many articles for the 'Encyklopädische Lexikon.' In 1829 he issued the first part of the Plants of the Prussian Pharmacopœia, as well as the German Poisonous Plants, and contributed to the 'Medical Encyclopædia.' Important works were completed in 1830, and he began monographs of the Myriopods and Oniscidæ, as well as a monograph of the Mammals founded upon Bürde's 'Abbildungen merkwürdiger Säugethiere.'

In 1831 he left Berlin with the title of Professor Extraordinary, and, through the influence of Humboldt and Rudolphi, went to the Academy of Sciences in St. Petersburg, first as assistant in and subsequently as director of the Zoological Museum. Here honours came thick upon him. He was elected an ordinary member of the Academy, became an Imperial Russian Councillor, received the title of Excellency, was invested with many distinguished orders, was elected into the Imp. Acad. Leop. Carol. and many of the academies and scientific societies of Europe. At the time of his Doctor's Jubilee in January 1876, his published scientific writings numbered 300. Of these 176 are zoological, 24 relate to comparative anatomy, 35 are palæontological, 11 are upon geographical zoology, and the remainder relate to archæological zoology, botany, and miscellaneous subjects. Brandt also published, in Helmersen and Schrenck's 'Contributions to a Knowledge of the Russian Empire and adjacent Lands of Asia,' a valuable and learned memoir on the progress of zoology in Russia between 1831 and 1879. He made great scientific journeys in Russia, first to Nicolajew in search of the mammoth, and afterward to the Caucasus to carry on his studies of its fish. He also visited and studied in the museums of Germany, Switzerland, Upper Italy, France, Belgium, Holland, and England.

Before going to St. Petersburg he married, and had a family of three daughters and four sons. The second son, Alexander, who has inherited his father's zoological and palæontological tendencies, is Conservator of the Zoological Museum in the University of St. Petersburg.

Brandt's palæontological writings relate to the fossil Mammalia. The most important of these is entitled 'Untersuchungen über die fossilen und subfossilen Cetaceen Europa's,' which gives a complete account of all the European Cetacea which were known down to 1873, and includes descriptions of species of *Cetotherium*, *Pachyacanthus*, *Cetotheriopsis*, *Cetotheriomorphus*, *Delphinapterus*, *Heterodelphis*, *Schizodelphis*, *Champsodelphis*, *Squalodon*, *Zeuglodon*, and other remarkable types. Other important memoirs relate to *Elasmotherium*, *Dinotherium*, *Rhytina*, and the Mammoth. Another important monograph is devoted to the characters of the Sirenia and their relations to various other orders; and many and important contributions were made by him to the knowledge of the osteology and structure of various other groups of mammals.

All Brandt's work is profound. His learning not only covers a wide field, but is brought to bear on difficult questions with singular concentration and ability. He has illuminated all that he has laboured upon. And as a palæontologist he will ever hold the highest rank, from the circumstance that his palæontological labours were merely the outcome of natural-history labours unusually exhaustive and lucid, and that these studies, which occupied the maturer years of his life, were treated in no isolated way, but with a full appreciation of their important bearing upon the higher philosophical questions which are the chiefest ends of scientific work.

On the Structure and Origin of Non-calcareous Stratified Rocks.

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Introduction.

In my address at our last Anniversary Meeting, I gave a general outline of what appeared to me to be the most important facts connected with the structure and origin of limestone. Having treated the question mainly from a new point of view, I did little else than describe my own observations. On the present occasion I propose to treat mainly on the structure and origin of non-calcareous stratified rocks, and to consider only those questions connected with igneous rocks which bear very directly on the subject before me. Some branches of this inquiry have already attracted much attention; but it would extend this address too much to discuss what has been writen on one detached portion or another. It will, I think, be better to give a summary of what appear to me to be the more important facts, as viewed from a general, and yet somewhat special, point of view. In doing this I must necessarily allude to many facts and conclusions which can have no claim to novelty, except in having been arrived at by more or less new methods, or in being discussed in a new connexion, or as bearing on more general questions.

Origin of Material.

Though the material of any more or less modern non-calcareous stratified deposit may have been derived from some analogous rock of earlier date, yet we must, I think, trace back the greater part to the mechanical breaking-up or chemical decomposition of igneous or metamorphic rocks, since in them by far the greater bulk of new crystalline material is formed. I therefore purpose now to consider the character of the sand and mud thus derived from different classes of rock.

The minerals of truly igneous rocks have been formed at an elevated temperature, and free from the continued solvent action of water. Though some are very stable, and do not undergo any material change when exposed to water at the ordinary temperature, yet many are altogether in a state of unstable equilibrium when exposed continuously to conditions so extremely different from those under which they were formed. Some of the constituents are dissolved out; and the rest group themselves in accordance with the new affinities, which vary according to special circumstances. Even in the case of those plutonic or metamorphic rocks which have been formed more or less under the influence of water, the temperature was apparently so elevated that the mutual affinities of the constituents were unlike those brought into play by exposure to the continued action of *cold* water, especially if it is charged with carbonic acid. When igneous or metamorphic rocks are weathered and broken up, we thus obtain sand and fine mud composed not only of the original materials, but also of products of chemical change. I shall therefore now consider some of the more important constituents of stratified deposits derived from certain typical rocks.

Quartz Sand.

The quartz of granitic rocks sometimes shows more or less imperfect crystalline planes, but is more commonly dovetailed in amongst the other minerals in a very intricate manner. The result is that in the rock itself the separate grains have often a most irregular and complex form, but yet on the whole are not much drawn out or flattened in any special direction. When the felspar is decomposed, and the rock broken up, some of the occasional special inequalities in the length, breadth, and thickness of the grains of quartz are reduced by cross fractures; and the resulting fragments are usually not more than, at all events, twice as long in any one direction as in any other, and have a very irregular imperfectly angular or imperfectly rounded outline. The quartz in quartzose felsites is often of much more truly crystalline form, the planes being sometimes very perfect; but very often there is a remarkable rounding of the angles, which might easily lead any one to think that they were waterworn. Even the grains of quartz derived from granite sometimes show this character to a less extent, but the rounding is usually accompanied by small surface-ridges, which clearly show that their rounded form was not due to mechanical wearing. In the specimens of decomposed granite which I have examined in greatest detail, the larger grains of quartz have a somewhat opaque surface, as if corroded, and the angles are rounded. This rounding is relatively much greater in the case of the smaller grains, which is the reverse of what is met with in worn sand. On the whole the facts seem to indicate that the quartz has been more or less corroded and dissolved by the action of the alkaline silicates set free by the decomposition of the felspar. The contrast between its corroded surface and the glassy fractures of broken quartz is very great.

The internal structure of the detached grains can be easily studied when they are mounted in Canada balsam, since its index of refraction is so nearly the same as that of quartz. High powers can easily be used, if we employ lenses of small angle of aperture having their focal point as remote as possible from the front lens. The shape of the grains, however, is better seen when they are in water under thin glass, since they can then be made to turn round so as to exhibit their form in more directions than one.

The quartz of thin-foliated gneiss and mica-schist differs from that of granite in having a far less simple optic structure, and in being often more or less flattened in the plane of foliation. Instead of the larger portions of quartz being made up of a few comparatively large crystals, they are frequently composed of very many, closely dovetailed together, as if formed *in situ*. Though the outline of these separate crystals is sometimes shown by more or less faint lines of impurity, they are often in such close contact that they cannot be separately distinguished without using polarized light. Such quartz, when broken up, would usually give rise, either to comparatively fine sand, or to larger grains showing a more or less compound structure. Besides this, in very thin-foliated rocks containing much mica, a large part of the quartz occurs as plates, flattened between the parallel flakes of mica; and when such a rock is broken up, we obtain flattened grains of quartz, with tolerably smooth surfaces, thus differing materially from the more irregular grains with rougher surfaces derived from granite.

Passing now to the internal microscopical structure of the individual grains, I must say that less can be learned from the fluid-cavities than might have been expected. Their number in the Scotch schists is, indeed, far less than in the Cornish granites, but not sensibly less than in some of the granite associated with them. I do not remember to have ever seen any cubic crystals of alkaline chlorides in the fluid-cavities in the quartz of any granite or schist from Scotland; but they occur abundantly in some Cornish granites. Hence, clearly enough, the evidence derived from fluid-cavities is of very limited value, except in particular cases. Far more characteristic evidence is furnished by the glassy and stony enclosures, when they are present. The quartz-crystals of some rhyolites contain small imperfectly rhombic or six-sided enclosures of coloured obsidian-like glass, with accompanying bubbles, even when the basis of the rock is no longer glassy. In quartz felsites, like some of the Cornish elvans, we see larger enclosures of a similar form; but, instead of being glass, they are devitrified and composed of fine-grained crystalline material, like the basis of the rock. No such stony enclosures occur in very typical granites; but we do meet with a few in those somewhat approaching felsites in general character. In the quartz of granites proper we see enclosed crystals of other minerals; and these may be very numerous and sufficiently characteristic of particular districts. Thus, for example, small prisms of schorl so abound in the quartz of Cornish granites, and fine needles of rutile in those of Scotland, that sands derived from them would certainly show very characteristic differences. I have been unable to detect any thing that would serve to distinguish the quartz of thick-foliated schists from that of true granite. In the case of thin-foliated schists it does, indeed, often enclose plates of mica, chiefly lying in the plane of foliation; and if broken up, very characteristic fragments would be formed, which might be called grains of mica-schist.

The quartz of veins sometimes differs so little from that of granite that I do not see how they could be distinguished. That from large massive veins could not fall to pieces to form sand, but would yield pebbles and small chips or granules; so that we can scarcely look upon it as an important source of sand of medium quality, which is what I propose to consider more particularly. Some of that derived from thick-foliated schists, and especially from gneiss, would not differ materially from that derived from certain varieties of granite; and it would also be impossible to say whether some had been derived from an abnormal granite, or from the mixed products of a granite and a felsite. Though we may thus expect to meet with many grains of quartz-sand presenting no distinctive peculiarities, yet some grains may still teach us their whole history, and throw much light on the true nature of the associated material.

Sand derived from other Minerals.

The felspars, augite, hornblende, schorl, and mica met with in different classes of rocks do not differ sufficiently in external form or internal structure to enable us to form any very satisfactory opinion as to their origin, except in a few particular cases. Thus, for example, the presence, or complete absence, of well-marked portions of enclosed glass would indicate that any fragment under examination was, or was not, derived from an igneous rock which solidified from a state of true igneous fusion. This does not necessarily prove that it was or was not a subaerial volcanic rock. The presence of cavities of more or less perfectly spherical form containing gas or vapour inside crystalline stony minerals, and the absence of fluid-cavities, is, on the whole, the most satisfactory evidence of their having been derived from a rock erupted under little pressure, or as a true ash. On the contrary, the presence of fluid-cavities, with or without included cubes of alkaline chlorides, would show that the mineral had been formed under considerable pressure, and might thus point out very clearly the origin of the fragment.

Mechanical Wearing of Material.

So far, I have considered the original form of the fragments, irrespective of subsequent mechanical wearing. In the case of fine sand the friction on the bottom must be very slight, since the weight of the particles is so small, and even a moderately agitated current of water would raise them from the bottom and carry them along almost without friction. When, however, the grains are larger, there is necessarily more friction—and still more so in the case of subaerial blown sand, since the pressure on the surface over which it is driven would be fully twice as great. The material thus worn off from separate grains, or from pebbles of quartzite or other hard rocks, would often be in such small particles that even its true mineral nature could scarcely be determined, much less the particular kind of rock from which it had been originally derived; and it would be difficult, if not impossible, to distinguish by the microscope particles thus produced by the mechanical wearing of stable minerals from those due to the chemical decomposition of those which are unstable.

Chemical Decomposition of Materials.

The change of felspar into kaolin is so well known that I need describe only the microscopical characters of the resulting material. When only partially decomposed, felspar becomes more or less opaque, owing to the formation of minute granules, but retains more or less of the original definite optic orientation. When completely decomposed, it is changed into a mass of minute granules having no more definite crystalline orientation than those in a small grain of hardened mud; and though these granules may cohere sufficiently to keep together, or may be cemented by other substances, yet in many cases they readily separate more or less completely. I have very carefully studied them, since they play such an important part in many stratified rocks. Their shape is very irregular; but they are not specially elongated or compressed in any particular direction, so that they cannot be called either irregular prisms or plates. Their diameter varies somewhat, but on an average may be said to be about $\frac{1}{10,000}$ of an inch. Their doubly refracting power must be somewhere about double that of quartz or unchanged felspar, so that grains $\frac{1}{2000}$ of an inch in diameter usually give with polarized light the pale blue-white of the first order; but those of $\frac{1}{20,000}$ or less in diameter are too small to give rise to any visible effects of depolarization.

Much of what I have just said will apply equally well to other minerals that can be changed into granules more or less closely corresponding to true kaolin, and also to the fine-grained felspathic base of felsites. I do not see how small fragments of felsite could be certainly distinguished from those derived from crystalline felspar, if the former did not reveal a more complex structure, or the latter retain some trace of crystalline form or internal optical structure.

Minute Calcareous Granules.

Whilst treating of the character of the minute granules derived from decomposed minerals, or from the complete wearing down of hard quartzose rocks, it will be well to point out how easily we may distinguish from them the calcareous granules derived from decomposed shells or comminuted limestones. Owing to the intense double refraction of calcite, calcareous granules give by depolarization tints of a much higher order than those given by the others. Thus, on an average, grains of $\frac{1}{1000}$ of an inch diameter give all the series of colours up to the reds and greens; and even those of $\frac{1}{10,000}$ give well-marked tints, commonly the yellow of the first order, but varying up to the red of the first order, according to the manner in which they lie. Moreover, in examining clays deposited in some parts of our country since the Cretaceous period, we may often recognize the coccoliths of the Chalk, not only by their very definite form, but also by the characteristic black cross which each gives with polarized light.

Pseudomorphs after Felspars.

As is well known, felspars occur altered to various pseudomorphs, the more important of which, in connexion with my subject, are mainly composed of chlorite, talc, or analogous minerals, which occur as plate-like crystals, having a very distinct laminar structure, to which the negative axis of depolarization is perpendicular. When these pseudomorphs are seen as thin sections, the laminar crystals cut transversely are much more distinct than those cut nearly in the plane of their cleavage; and it sometimes requires much attention to distinguish between a mass of such laminæ and small prisms scattered about in a different kind of material. Thus, for example, when altered to chlorite or some green variety of talc, the transverse sections are but little coloured, and appear like fibres surrounded by a green uncrystalline base; but further examination shows that they are very dichroic, and that the green and apparently shapeless material is really only laminæ lying in the plane of the section, so that the line of vision is nearly in the line of the optic axis. They therefore show the green colour with ordinary light, and no colours due to depolarization when the polarizer and analyzer are used.

Some portions of what appears to have been felspar have, to a certain extent, been changed into small more or less flattened fibrous crystals, which in many characters approach asbestos, though it is doubtful if they really are that mineral. At all events this seems to be the most probable source of the small fibrous crystals often associated with kaolin, but differing from it not only in form, but also in having a much more powerful depolarizing action. They are well seen in the pipeclay of Kingsteignton, and occur in greater or less numbers in most fine-grained clays.

Identification of some Minerals.

In distinguishing from one another different kinds of small laminar or prismatic crystals, I have found it most valuable, and, indeed, indispensable, to make use of the quartz wedge inserted into the eye-piece like a micrometer described by me in a paper read before the Royal Microscopical Society*. Minute portions of minerals which appear identical, when examined with a simple polarizing microscope, may often be distinguished by it with great ease. Thus, for example, if we have a more or less transverse section of a laminar mineral like mica, and rotate it in polarized light, at two different azimuths at right angles to one another it does not depolarize. These directions may be very conveniently called the "axes of depolarization." They are not exactly the axes of elasticity, but are the direction along which these axes intersect the section in the line of vision. Arranging the section on the stage of the microscope so that one of these axes is at an angle of 45° to the plane of polarization, we, of course, see to the greatest advantage the colours due to depolarization. Pushing the quartz wedge into the eyepiece, with the axis also at 45° to the plane of polarization, the tints given by the object under examination are raised if its positive axis be parallel to it, but lowered when it is the negative axis which is parallel. In this latter case, when the part of the wedge which gives the same tint as the section is over it, the object appears black. If the depolarization is extremely feeble, it is difficult to see this, because the object must be observed so close to the extreme thin edge of the plate. It is then much better to notice whether the object lowers the blue of the second order to the red-orange of the first order, or raises the latter to the former. In the case of mica cut more or less transversely we can thus easily see that the negative axis of depolarization is invariably at right angles to the laminæ, whereas in some other analogous minerals this axis is positive. In the case of some prismatic or fibrous minerals, like hornblende, the positive axis appears to be somewhat variably inclined to the line of the fibres. This is because the true axis of elasticity is not parallel to the axis of the prism, and thus the result depends partly on the manner in which the crystal happens to be turned on its axis in the plane of the section. This alone is a very important fact; but we should also observe whether, when the axis of depolarization is parallel to the fibre, it is negative or positive. Unlike hornblende or transverse sections of mica, small prismatic felspar microliths have their negative axis more or less nearly in the line of their length. The angle at which it is inclined differs in different kinds

* Monthly Microscop. Journ. 1877, vol. xviii. p. 209.

of felspar, and sometimes also with the direction in which each simple or twin crystal is cut. It will thus be seen that the quartz wedge furnishes us with a most valuable means for distinguishing very minute crystals. It is also very useful in enabling us more easily and accurately to compare the doubly refracting power of different minerals, as shown by the order of the tints given by contiguous sections of the same thickness, observing the average result, so as not to be led into error by the varying inclination of the axes to the plane of the section.

Mica in deposited Rocks.

Though the larger crystals of mica in granite or schists may be somewhat altered by weathering, the microscopical and optical characters are not sufficiently changed to need special description. Unless it be in special cases, when much oxide of iron is present, there seems to be no other general tendency to fall to pieces than by breaking up along the cleavage into thin flat plates. Except when forming part of a boulder or pebble, mica could not be much worn down by friction, since its shape would cause it to be so readily lifted from the bottom by a current. There is, however, a most important source of very fine-grained micaceous mud, which I was not able to recognize until very recently for lack of adequate optical apparatus. I have long known that some quartz felsites might almost be called extremely fine-grained granites, and contain many small flakes of mica, plainly visible with a pocket-lens; but it was not until I had found that the quartz wedge in the eyepiece enables us to distinguish transverse sections of very minute flakes of mica from felspar microliths that I was able to prove that, though the fine-grained base of some felsites is mainly felspathic, yet that of others contains a very considerable amount of mica. This occurs in the form of minute flakes, varying in size down to about $\frac{1}{2000}$ of an inch in diameter, and $\frac{1}{20,000}$ of an inch in thickness. Such flakes are of course far too small to produce any very marked difference in the natural appearance of the rock. The decomposition of such a felsite would yield a very fine-grained mud, composed not merely of kaolin, but also of mica, or at least of some mineral having very similar mechanical and optical characters.

Augite, Hornblende, and Olivine in deposited Rocks.

Much of what I have said respecting the internal structure of felspar will apply equally well to augite, hornblende, and olivine. Little could be learned about the origin of any particular fragment unless it contained well-marked glass enclosures or bubbles of gas, which would point to a true volcanic origin. Not much reliance could be placed on the mere absence of bubbles, yet their complete absence would make it more probable that the material was derived from a solid volcanic rock and was not a true ash.

If decomposed by weathering near the surface, augite and hornblende are to a large extent removed, and little remains but peroxide of iron and any minute included crystals of insoluble minerals. The space originally occupied by the removed material may be left comparatively empty, or be filled with calcite or other minerals commonly introduced into minute fissures or cavities. Augite, hornblende, and olivine, however, are often changed in a very different manner, and give rise to pseudomorphs of various kinds, probably when the change was effected at a higher temperature, or, at all events, less under the influence of the atmosphere. By far the most important of these pseudomorphs are of a green colour, but differ much in the mechanical and optical structure of the material.

It would be tedious and occupy far too much time to consider separately all the other minerals which, in a broken-up or decomposed condition, to a less extent serve to give rise to the material of stratified rocks; those I have selected will, I trust, serve to illustrate what appear to be the principal phenomena attending the formation of different kinds of sand, mud, and clay. It is, however, very essential that we should consider the glassy base of volcanic rocks.

Volcanic Glass and Ashes in deposited Rocks.

The general structure of obsidian, pitchstone, tachylite, and similar rocks has been described by so many authors that I need say little about it. Their general base is a true glass, having no depolarizing action on polarized light. This property, of course, serves at once to distinguish it from fragments of very many of the more common minerals, but not from isotropic minerals like garnet. However, in many cases the presence of bubbles, or of a fluidal or vesicular structure, shows very clearly that the substance under examination is a true volcanic glass. In addition to this internal structure, the fragments have often a very characteristic form. The melted glass may have been blown into spray, and given rise to fibres and irregular spherical bulbs, as in the case of *Pélé's hair*; or it may have been blown out by the internal evolution of gas or steam into a more or less perfect pumice. The form and structure of this latter are so characteristic that there is little chance of confounding minute fragments of it with any thing else.

Speaking generally, we may say that particles of pumice are made up of cells with more or less curved walls of glass which occasionally are not more than $\frac{1}{10,000}$ of an inch in thickness. When broken very small, the particles may show no entire cells, but merely curious irregular compound plates, due to the meeting of several cells, or simply more or less curved laminæ derived from cell-walls. There is a gradual passage from such vesicular glassy material to solid crystalline lavas; and only an occasional fragment in a mass of ash may be decidedly vesicular or contain true glass. In only a few cases, like that of *Pélé's hair*, could we be certain that the ultimate particles had been formed by a true volcanic process. In some cases it would be impossible to distinguish between a volcanic rock reduced to fragments during an eruption, so as to give rise to a true ash, and the same rock broken up after consolidation by non-volcanic action. Still, on the whole, I think we may look upon the vesicular structure of the constituent materials or base as characteristic of *ash*, and the more rounded and worn shape of the fragments as characteristic of what, for distinction, we may call volcanic *sand*.

Microscopical Examination of Sands and Clays.

Having considered the origin of the material in as much detail as seems desirable, I now proceed to describe the methods which I have found best in studying particular examples of sands and clays. On the whole, the most useful power is a $\frac{1}{5}$, since that enables us to see nearly all the detail; but for examining the mere shape of grains of sand and the coarser structure of rocks, a $\frac{4}{10}$ or even a $\frac{2}{3}$ is more convenient. It is only occasionally that so high a power as $\frac{1}{8}$ is needed, and that chiefly to determine the true characters of very minute cavities. On the whole, there can be no doubt that far more may be learned from thin microscopical sections than from loose material; but yet very much may be learned even in this latter case, and in fact more respecting certain particulars. The general form of the particles is best observed by viewing the sand or mud in water under thin glass. Their outline is then much better seen than when they are mounted in Canada balsam; and by slightly moving the cover-glass, they turn round so as to show their entire shape, or slip along the surface of the supporting glass in such a manner as to prove that they are thin flat plates. The internal structure and optical characters of the constituent particles, however, are far better shown when the deposit is mounted in Canada balsam. I have found it best to first spread out the material on the glass in dilute gum and water. This, on drying, leaves the grains sufficiently fixed on the glass to prevent their moving either during the mounting in balsam or when the slide is afterwards kept in a vertical position. Although when thus mounted it is impossible to make the grains turn round, yet much may be learned respecting their shape by observing the tints which they give with polarized light. Thus, for example, a more or less spherical grain of quartz sand about $\frac{1}{100}$ of an inch in diameter gives, on an average, tints rising from the faint white-blue of the first order at the edges up to the well-marked colours of the second and third orders in the centre, whereas a grain of that diameter, if it were thin and flat, would give over a large part of its surface nearly uniform tints of a lower order.

Identification of the Minerals in Sand.

Occasionally it might require some care to distinguish between flat plates of quartz and flakes of mica; but by careful examination with an adequate power the more truly laminar structure and parallel faces of mica enable an observer to distinguish it from quartz or any other common constituent of sands or clays. There is usually no serious difficulty in identifying the grains of the other constituent minerals by their form or optical characters. Quartz can generally be distinguished from the triclinic felspars by the compound twin striation of the latter, and from orthoclase by the difference in general shape. Quartz, having no cleavage, breaks into grains of most irregular form, whereas orthoclase, having well-pronounced cleavage, very often occurs in flat pieces showing more or less of straight parallel edges; it also very often differs in being more or less opaque from partial decomposition. However, when very transparent and the cleavage indistinct, as it is sometimes in the glassy felspar of volcanic rocks, it requires much care to distinguish it from quartz, since the form of the fragments and their action on polarized light are very similar. When neither fluid-cavities nor other enclosures are present to indicate which of the two minerals is under examination, the only distinction that I have been able to discover depends on the slightly less refractive power of glassy felspar, which causes the outline of the fragments to be more distinct when mounted in *hard* Canada balsam than that of quartz grains, which have almost exactly the same refractive power as hard balsam. It would, however, scarcely be in place on the present occasion to describe in detail all the characters which enable an observer to identify every constituent mineral, though it was, as I think, desirable to describe some of the more important, in order that a better opinion might be formed respecting the amount of confidence that should be placed in my general results.

Identification of Fragments of Rocks in Sand.

The difficulty of determining the true nature of each particular grain is greatly increased when we have to deal with fragments of rocks. This of course differs as much from studying the structure of a known rock, as the determination of the true nature of any single unknown bone differs from the study of the entire skeleton of some well-known animal; and in like manner it is necessary to pay attention to matters of detail which otherwise might be overlooked. The grains also may be, and often are, too small to show such characters as would suffice to identify the rock on a larger scale; and separate fragments may differ as much as though they were different rocks, and yet may have been closely associated in the same rock. It is also sometimes difficult to distinguish between such very different objects as grains of partially decomposed felspar, decomposed felsite, or slates formed from similar material, especially when we can examine only loose fragments and not a thin section. Still, notwithstanding all these difficulties, to which we should be fully alive, by one means or other very much may be learned, even though in many cases the conclusions may be open to a certain amount of doubt in some particulars.

Flint Sand.

At one time I fully expected to find that the sand associated with flint-gravel was itself mainly flint; but I found that, in some cases at all events, it is chiefly of the normal kind. When polarized light is used, there is no difficulty in distinguishing between flint and quartz grains. The latter have a simple optic structure, and, when rotated, look alternately wholly dark or bright; whereas flint has a very compound crystalline structure, and at all azimuths shows almost the same characteristic speckled granular appearance. Jasper has a very similar structure; and quartz containing many minute crystalline granules might present a very similar appearance in those few cases in which the principal axis of the crystal happened to lie in the line of vision. Though sometimes met with in well-rounded grains, flint often occurs as thin flat chips, no doubt on account of its peculiar kind of fracture.

General Characters of Sands.

I have already said enough respecting the general characters of the more important constituents of sands. It now remains for me to consider the external form and internal structure of the separate grains. In these respects different sands may differ very strikingly.

External Form of the Grains.

The true character of the surface is best seen by examining with transmitted light the loose material unmounted, using a condenser, so as to prevent too great a shadow round the edges of the grains. In observing their form we must not compare the quartz of one specimen with the felspar of another, nor the larger grains of one with the smaller of another. All our comparisons must be made between grains of quartz of nearly the same medium size in a clean condition. For this reason the sand should be well washed in water, using a small stiff brush to thoroughly detach adherent mud. When dry, the coarsest particles should be separated by one sieve, and the finest by another, so as to obtain for comparison sand of tolerably uniform size. The coarser sieve which I employ allows grains of about $\frac{1}{70}$ of an inch in diameter to pass through; and the smaller keeps back all greater than $\frac{1}{120}$, so that the average size of the grains used for comparison is about $\frac{1}{100}$ of an inch. The importance of comparing grains of nearly the same size is at once apparent when we examine the different portions thus separated. The coarsest are sometimes nearly all much rounded when the finest are nearly all very angular, no doubt because the friction of such small particles on the bottom is so very trifling. It is the grains of medium size which are the most suitable for observation in comparing different specimens.

Having thus prepared a good sample of medium quality, care must be taken to mix it thoroughly, and to spread a small portion evenly, but somewhat closely, dry, on a glass plate, kept horizontal, in such a manner as to prevent the rounded grains separating from the flat and angular, which they do so readily that great errors might otherwise result. By proceeding in this manner, and by examining a considerable number of specimens of various geological periods and from various localities, I have found that quartz sands, although to the naked eye appearing very similar, may be divided into five types, which, though characteristically distinct, gradually pass one into the other. They are as follows:—

1. Normal, angular, fresh-formed sand, as derived almost directly from granitic or schistose rocks.

2. Well-worn sand in rounded grains, the original angles being completely lost, and the surface looking like fine ground glass.

3. Sand mechanically broken into sharp angular chips, showing a glassy fracture.

4. Sand having the grains chemically corroded, so as to produce a peculiar texture of the surface, differing from that of worn grains or crystals.

5. Sand in which the grains have a perfect crystalline outline, in some cases undoubtedly due to the deposition of quartz over rounded or angular nuclei of ordinary non-crystalline sand.

On the whole, then, we may say that these different types are due to different kinds of mechanical or chemical changes, affecting grains originally derived from crystalline rocks.

Now I do not know what others may have thought or done, but must confess that until very recently I had no idea that the differences between different specimens of sand were so great. I am very sorry that in years gone by I did not collect a sufficient number of specimens to enable me to decide several interesting questions, and think myself fortunate in having collected what I have without foreseeing their ultimate value for the purpose now in hand.

Variously worn Sands.

In the first place it is most important to distinguish between the *age* of the *grains* and the *age* of a *deposit*. A very ancient sand bed may be made up of grains which are practically new and unworn, whilst, on the contrary, the grains of a modern sea-beach may be of vast antiquity, may have passed through the greatest vicissitudes, may have successively formed a part of several different geological formations, and may be greatly altered and worn. Unfortunately I am not acquainted with sufficient facts to prove how long it would require to thoroughly wear down and round a grain $\frac{1}{100}$ of an inch in diameter. It is evidently a very different thing from the wearing down 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 always be small. The following considerations will serve to make this more clear. The friction on the bottom must vary directly as the weight, and therefore as the cube of the diameter; but the surface from which the material must be worn varies as the square of the diameter. Hence, even making no allowance for the extra buoying-up of very minute particles by a current of water, depending on surface-cohesion, the effect of wearing on the form of the grains must vary directly as their diameter or thereabouts. If so, a grain $\frac{1}{10}$ of an inch in diameter would be worn ten times as much as one $\frac{1}{100}$ of an inch in diameter, and at least a hundred times as much as one $\frac{1}{1000}$ of an inch in diameter. Perhaps, then, we may conclude that a grain $\frac{1}{10}$ of an inch in diameter would be worn as much or more in drifting a mile, as one $\frac{1}{1000}$ of an inch in being drifted 100 miles. On the same principle a pebble 1 inch in diameter would be worn relatively more by being drifted only a few hundred yards. As far as I am able to judge, these conclusions agree well enough with the general facts; but yet better evidence of the actual time and distance required to wear grains round is still much to be desired. In the absence of positive proof, I will describe certain facts which seem to throw light on this question.

The wearing down and rounding of the original angular grains is, of course, a gradual process; and we meet with every connecting link between the two extremes, even in the same specimen. This may be due to a mixture of grains much worn by backward and forward action with those more directly drifted from their source. It is therefore difficult to decide what is the true proportion of angular and rounded grains in each particular case. Still this may be done by counting the total number, and also the number of those that are well worn, in several fields of the microscope, so as to obtain a good average. This ratio, of course, represents the relative total wearing, whether due to actual transport or local backward and forward movement; but in average conditions this might so vary directly with the amount of transport as to make it indicate approximately the relative distance of the source of supply.

Sand washed from the Boulder-clay at Scarborough.—This is almost entirely fresh and angular, showing few or no rounded grains. Hence, though the material may have travelled far, it was not worn, which fully agrees with the glacial origin of Boulder-clay. Some of the sand-beds of drift-age do, however, contain many well-worn grains, probably owing to continued local wear and tear.

Sand from the modern beach at Scarborough.—This must have been subjected to the action of the waves for a considerable time; and yet it is little, if at all, more worn than that in the Boulder-clay, from which probably it was in great measure derived. Until I had examined the well-worn sands of the south-east of England, the angularity of the Scarborough sand led me to believe that it was characteristic of all such fine-grained deposits.

Sand of the river-terraces at Dunkeld.—This is just as if mainly derived from schists. It is almost wholly angular, thus proving that the grains are very little worn by drifting down a river.

Sand of the Millstone Grit and Lower Coal-measures of South Yorkshire.—This is as sharp and angular as if derived almost directly from decomposed granite, the slight corrosion being no more than normal. I have long ago shown that this material was drifted from the north-east, and was mainly derived from granitic rocks probably lying in that direction, but now no longer visible. They must, however, I think, have been at a considerable distance; and yet we see that the grains were very little, if at all, worn in being drifted so far along the bottom, even if we altogether disregard the effects of local agitation.

Taking, then, all the above facts into consideration, 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. I now proceed to consider what appears to me a good illustration of how this wearing-down may be explained when it does occur.

Green Sand of the South of England.—I have examined specimens taken in various places from Devonshire to Kent; and the facts seem as though they would be of much interest if confirmed by more complete examination. In the Haldon-Hill district the grains are mainly angular, only $\frac{1}{10}$ being well worn. Passing to the Isle of Wight this rate increases to $\frac{1}{5}$; and in Sussex and Kent it further increases to $\frac{1}{3}$ and $\frac{1}{2}$. I must say that I feel much tempted to explain these facts by supposing that on the flanks of Dartmoor we are near to the granitic rocks from which the sand was derived, and that in being drifted from it further and further eastward, the grains were more and more worn. This does, indeed, seem so very probable, that perhaps we may provisionally adopt some such explanation of the facts.

Hastings Sand, &c.—This conclusion is strengthened by the character of the other sands of the S.E. of England. The Hastings Sand at Hastings, and the Thanet Sand from Crossness are about $\frac{1}{3}$ worn, and that of the modern Thames, near Richmond, about $\frac{1}{2}$ worn, which is in striking contrast with the perfect angularity of the sand of the Tay, and clearly indicates the great antiquity of the grains and the great distance to which, at one time or other, they have been drifted from their original source in crystalline rocks.

New Red Sandstone.—I have examined a number of specimens from various places, extending from Scotland right down to Devonshire; and what struck me most was the comparatively uniform extent of the wearing. My estimates of the relative number of well-worn grains varied from $\frac{1}{5}$ to $\frac{1}{3}$. The only important difference is in a specimen from Leamington, which is so far corroded that the angular grains appear more numerous.

We can thus draw no very certain conclusion as to the source of the material, unless indeed it be that we as it were cross the line of drifting transversely in passing from north to south. The modern sand of the dunes at Southport is no more worn than that of the beach; and both are very much like the New Red Sandstone, from which probably they have been mainly derived.

Lower New Red, &c.—I have already referred to the extreme angularity of the grains in the Lower Coal-measures of South

Yorkshire. In the Upper Coal-measures, and in the Lower New Red, the wearing is greater, and approaches that of the New Red.

As an example of extreme wearing, I would refer to the blown sand of the Egyptian desert, in which almost all the grains are rounded, evidently on account of the material having been drifted about by the wind for a long period.

I very much regret that I have not been able to treat this question of the wearing of sand in a more satisfactory manner, but yet hope that what I have said may, at all events, serve to prove that we may thus learn whether sand is of recent and comparatively local origin, or very ancient and transported far from its original source by drifting along the bottom.

Fractured Grains.

We now come to another kind of mechanical change, viz. not wearing, but fracture. That this does occur is clearly shown by the occurrence of well-worn rounded grains which have been broken across, and by the occasionally large number of true splinters and chips. Still, on the whole, the amount of change due to fracture does not appear to be great, and it is only in a few instances that it becomes an important feature of grains $\frac{1}{100}$ of an inch in diameter. The most striking example I have seen is a specimen from the Greensand near Aylesford, which appears to indicate some unusually violent local action.

Corroded Sands.

As I have already said, the quartz grains in decomposed granite appear as if corroded. Many specimens of sand also show what is probably only this original corrosion; but sometimes it appears to have taken place after the grains had been worn and deposited. In typical examples the surface has a peculiar texture, differing from that due to mechanical wearing or to crystallization. I am by no means sure that occasionally corrosion has not taken place in one part and deposition of quartz in another, even in the case of individual grains. The extent of the corrosion, however, is usually very small, and the irregular solution of $\frac{1}{1000}$ part of an inch from the surface would explain all the appearances. That well-rounded grains in porous sandstones may retain perfectly all the original characters, though water could, and probably has, largely passed through the rock, is clearly proved by some specimens of the New Red. Considering that we could easily detect the irregular removal of $\frac{1}{10000}$ of an inch, the solubility of quartz in water must therefore be so small that it may well be said to be insoluble. Perhaps, when corrosion has occurred, it is evidence of the former presence of water rendered alkaline by the decomposition of associated felspar.

The best examples of corrosion that I have seen are from the sand below the Magnesian Limestone at Conisbrough, from the New Red at Leamington, and from the Wealden at Mark Cross.

Sand with Quartz chemically deposited on the surface of the grains.

Many authors have already described what they have called *crystallized sand*; but I think they have often mistaken its true nature. In some cases, if not in all, the grains are not quartz simply deposited in a crystalline form, but are sand of perfectly normal character, on the outer surface of which a greater or less amount of quartz has been deposited in crystalline continuity with that of the original nuclei. The phenomena are like what happens when an irregular fragment of a soluble crystal is placed in a concentrated solution of the same salt slowly evaporating. The first stage of the process is the restoration of the broken angles; and then deposition goes on over the whole exposed surface, in perfect optical and crystalline continuity, so as to change a broken fragment into a definite crystal. We observe precisely the same facts in the case of the sands now under consideration.

Good examples of the early stage of the process are seen in the Old Red of Cockburnspath. The original grains are composed of quartz containing cavities and granules, whereas that deposited on the surface is quite clear, and the line of junction often perfectly distinct. Deposition, to any marked extent, has taken place only over a few; and in almost every case merely the pyramidal ends of the crystals have been reproduced, as shown by fig. 1.

Fig. 1.—*Sand-grain with slight deposition of Quartz.*

Fig. 2.—*Sand-grain with much Quartz deposited on the surface.*

The more complete development of a crystalline form, by deposition over the whole surface, is well seen in the sand of the Vosges, described by M. Daubrée, to whom I am indebted for a specimen. The nuclei of original waterworn sand are composed of quartz containing many cavities and granules; the outer surface is rough and discoloured; and over the whole very limpid quartz has been deposited; so that the contrast is very marked. None has been deposited on the surface of the felspar grains; and when a grain is composed partly of quartz and partly of felspar, the deposit has taken place only on the quartz, as in the case shown by fig. 2, which exhibits all the above-named facts somewhat unusually well. The original nucleus and the deposited quartz are always in crystalline continuity; so that, when rotated in polarized light, both turn dark and light simultaneously.

The contrast between the original nuclei and the subsequently deposited quartz is also very well seen in the case of a specimen of the New Red Sandstone from Penrith, kindly given to me by Prof. Morris, since the nuclei are stained red whilst the deposited quartz is colourless, as may be seen at once by examining the sand in benzol. We thus also learn that the reddening of the grains took place before the deposition of the quartz.

As will be readily understood, if the original nucleus were composed of perfectly limpid quartz, it would be impossible to distinguish between it and the subsequent deposit. Possibly this is why I can detect no nuclei in the crystallized oolitic sand at Scarborough, and thus there is no positive evidence that the whole was not deposited chemically.

The source of the quartz thus chemically deposited on the grains of sand is by no means clear. In some cases it may be derived from the decomposition of associated felspar; but much decomposed felspar may be present without any such deposition. Possibly some of the more striking examples are due to the special local action of heated water, as shown by M. Daubrée in the case of the Vosges sand.

I have met with crystallized sand in deposits of various ages, from the Oolites down to the Old Red. Most of the specimens were very friable, and the grains but little coherent. In some cases, as in the Oolitic sand at Scarborough, this is apparently due to the removal of what were perhaps grains of shell-sand; but still there is sufficiently good evidence that quartz has been deposited *in situ*. In some other specimens, like the New Red of Penrith, a number of grains may often be seen cohering more strongly than the rest; and these show clearly that the cavities originally existing between the grains have been more or less completely filled with quartz. Moreover, on carefully examining the less-coherent grains by surface-illumination, we can see, not only the planes and angles due to unimpeded crystallization, but also more or less deep impressions, due to the interference of contiguous grains, thus proving conclusively that the deposition of crystalline quartz took place after the nuclei were deposited as a bed of normal sand. The very imperfect consolidation sometimes met with is, perhaps, not so very surprising when we reflect on the very small coherence of many large quartz crystals which are yet in close juxtaposition. However, it does seem probable that this crystallization of quartz sometimes contributes very materially to the cohesion of the grains in hard and compact quartzites. In such examples as the Gannister of the South Yorkshire coal-field we can see, in a thin section, that the grains fit alongside one another in a very striking manner, and it is only by extreme care that good proof can be obtained of the actual deposition of quartz between them. However, in the case of a highly consolidated sandstone from Trinidad the proof of the deposition of quartz is as complete as possible: the outline of the original grains of sand is perfectly distinct; and the cavities between them are filled with clear quartz in crystalline continuity with the contiguous grains; so that the whole is a mass of interfering crystals, each having a sand-grain as a nucleus. The rock has thus been converted into a hard quartzite, almost like a true quartz rock, but differs from such quartz rocks as those of the Scotch Highlands in containing no mica crystallized *in situ*. All my specimens of these quartz rocks are really highly quartzose mica-schists; and, so far, I have failed in my endeavours to trace the connexion between them and true sandstones, though possibly this could easily be done in some districts which I have not examined.

We can thus trace the history of quartz-sand from its origin in crystalline rocks through different mechanical and chemical changes, all of which may be paralleled with what has occurred in the case of the calcareous sand derived from organic bodies. As shown in my address last year, we have in them a falling to pieces by decay, a mechanical breaking up and wearing down, as well as corrosion and the subsequent deposition of calcite; but of course many of the facts are very different, on account of the totally different chemical properties of carbonate of lime and quartz.

Internal Structure of the Grains.

Having now considered the external form of the grains, it remains to consider their internal structure in a few special examples.

Millstone Grit of the neighbourhood of Sheffield.—The grains of quartz are, on the whole, extremely angular, and, as a general rule, show little trace of wearing; so that portions of decomposed felspar still frequently fill irregularities on the surface, and greatly interfere with our view of the internal structure. A few fragments of undecomposed felspar also occur; but the greater number have been decomposed, and the kaolin squeezed in between the grains of quartz. Occasionally we meet with what may be called grains of granite. On the whole, by far the greater part of the material is as if derived from decomposed granite; but a few grains are as if derived from schists. The occasional occurrence of pebbles of a somewhat coarse-grained granite, along with many composed entirely of quartz or felspar, strongly confirms the conclusion thus arrived at from the study of the grains of sand. The internal structure of the quartz indicates that the granite was of a type differing from many others; but one of the most striking characters is that there are many very minute fluid-cavities, with most unusually minute bubbles, moving about with extreme apparent rapidity. Some grains contain flakes of mica; schorl is rare, if not absent; but hair-like crystals of rutile are common.

Blown Sand of the Egyptian Desert.—This is an admirably extreme example of blown sand, differing in a remarkable manner from the Millstone Grit. The grains seldom show any sharp angles, and are usually so much worn that the original external surface must have been almost wholly removed. A few are worn down to nearly perfect spheres. Some are flat, as though derived from schists; but by far the greater part are as if derived from granite and felsite, or from some rock of intermediate character. Fluid-cavities are not common; but when they occur they are somewhat large for granite. A few enclosed particles of felsite paste may be seen, and also, in some cases, flakes of mica or crystals of schorl. Occasionally we see grains of jasper. On the whole it appears as though this sand had been derived from rocks of varying type.

Modern Sand of the Thames.—Flint-sand plays an important part in the modern deposits of the Thames. By counting a large number of grains seen under the microscope, I found that between Richmond and Brentford the proportion of flint to the entire amount of siliceous sand is about $4\frac{1}{2}$ per cent., but decreases as we pass down the river, until near Gravesend it is reduced to less than 3 per cent. I have no doubt that a large part of this is derived from the flint-gravel used to make or repair the roads, since the drift from them contains 10 or 20 per cent., and occasionally more. In the old deposits of the Thames valley, like the sand of Hyde Park or the Thanet Sand, the amount of flint is only 1 per cent.; and thus in such a district we might form some idea as to the relative age of different more or less modern deposits. I may also here allude to the occasional large amount of coke dust and rounded or angular grains of coal in very modern sand beds or mud banks formed in the neighbourhood of a large population.

Terrace-sand in the valley of the Tay at Dunkeld.—This is a good example of sand derived from schists. The most striking feature is that the fragments of quartz are, on the whole, much flattened, and contain very few fluid-cavities. These are associated with many flakes of green and colourless mica, and with fragments of hornblende, as well as a few of garnet and other minerals. Amongst the coarser grains are many of true mica-schist not broken up into its separate constituents.

Trias Sand at Paignton.—This contains many rounded fragments of what appears to have been a hard slate rock, distinguished from grains of partially decomposed felspar by the presence of the usual minute hair-like crystals of black oxide of iron lying in the plane of cleavage. The associated quartz grains are a little, but not much, worn, and indicate that they were derived from both granites and schists.

These few examples must be looked upon merely as illustrations of what may be learned by studying the grains in detail; and further and more striking examples will be described when treating of slate-rocks and schists.

Mud and Clay.

I do not see how it would be possible to ascertain the true nature of the rock which gave rise to the kaolin or other minute granules met with in mud or clay, unless it were by observing their connexion with other associated materials. As far as the individual particles are concerned, we can do little more than distinguish between more or less irregular granules, minute flakes of mica, and needle-like prisms. In many cases it would be difficult or impossible, even to decide to what mineral species such minute granules belong; and in using the term *mica*, it must be understood that I do not mean any one particular mineral, but rather any of those minerals which have the same laminar structure as mica, and an axis of elasticity perpendicular to the laminæ, along which the double refraction is negative. Still, notwithstanding these difficulties, a good deal may be learned in one way or other.

The most striking differences between different specimens of mud and clay depend on a greater or less variation in the amount of mica, calcareous granules, and sand mixed with the unidentifiable granules; but these differences do not necessarily enable us to trace the material to its true source. Larger grains of compound rocks, either in the clay itself or in closely associated beds, may, however, furnish good evidence of the true origin of the material, if proper allowance be made for the hardness of the various rocks or minerals. It is very important to do this, since the larger compound fragments may represent only the very hardest rocks, and the great mass of the fine-grained mud may have been derived from associated soft rocks which have been completely disintegrated.

It would extend this address to an unreasonable length to describe in detail the structure of our various groups of stratified rocks; and before any general conclusions could be formed it would be necessary to examine a very extensive series of specimens. Still the method I now describe does seem to lead to some valuable results, even though I have been able to apply it to only a limited extent.

In the more modern strata, down to the Devonians, the sandy beds of which are mainly composed of quartz grains derived chiefly from granite when coarse, and from schists when fine, the associated clays and shales very commonly contain scattered grains of similar sand, but are chiefly composed of minute granules of decomposed felspar, flakes of mica, and the other minute particles already mentioned. Compared with the deposits of the deep oceans, many of our more modern fine-grained mud deposits are characterized not only by the absence of minute calcareous organisms, but also by the comparative absence of pumice and other true volcanic products. I hesitate to affirm that pumice is completely absent. It certainly does occur abundantly in some of the Carboniferous strata of Scotland, which are associated with erupted rocks; and, judging from its remarkably wide distribution in the modern oceanic deposits brought back by the 'Challenger,' I am quite prepared to meet with it occasionally in many of our stratified rocks, which I have not yet adequately examined to decide this special point.

Deposits mainly composed of inert substances like quartz, mica, and kaolin can undergo little further change. The complete decomposition of the felspar, however, may not occur until after the material has been deposited; and its further decomposition may give rise to quartz or opal; and the decomposition of the hornblende and analogous minerals may also give rise to silicates of iron and other products, formed *in situ*. The amount of such changes does not appear to have been very considerable in the case of most of our more recent English rocks; but still I think we must attribute to it some well-marked characters, and a more or less considerable share in cementing the grains together to form a hardened rock. It is more especially in the case of volcanic ashes that we should expect to find this sort of action at a maximum, since they are often to such a large extent composed of unstable minerals, ready to undergo great changes when surrounded by wet mud.

Lamination of Shales, &c.

I am sure that most geologists must have been struck with the great similarity between the laminar fracture of many shales and the cleavage of imperfect slates. It is, in fact, a sort of cleavage in the plane of stratification. I do not refer to thin beds of different mineral character in the plane of deposition, but to the more irregular lamination of thick-bedded shales.

In order to throw light on this question I made a careful experiment with some fine-grained mud from 2600 fathoms in the South Pacific, collected by the 'Challenger.' Such fine-grained muds have a very peculiar property, which must play an important part in their origin and structure. When suspended in water the grains of sand which they contain do not separate and subside quickly, and leave the fine mud suspended for a long time; but the coarser and the finest particles rapidly coalesce into compound granules, which subside at a more uniform and intermediate rate, soon leaving the water clear. This property readily explains why such fine-grained mud so often contains grains of sand. By gentle agitation the coalescence may be to some extent prevented. Now, having mixed some of this Pacific mud with water, and having kept it until no further subsidence occurred in several weeks, I determined the amounts of water and solid matter in the stiff pasty deposit, and found that the actual bulk of the solid matter was only 11 per cent. of the whole, and that the spec. grav. of this solid matter was 2·65. As far as I can judge, the volume of the solid matter in shales containing no infiltrated matter may be considered to be at least 75 per cent.; and hence the squeezing-out of the water from material like the simply deposited Pacific mud to form such a shale, would reduce the thickness to at least one sixth. Such a change would be quite adequate to develop a fissile structure nearly in the plane of bedding, which, however, could not be so perfect as the cleavage in the best slates, on account of the ultimate particles being chiefly granules and not laminæ.

Slate Rocks in general.

In studying cleaved slate rocks it is sometimes most important to prepare and examine sections cut in several different directions. I strongly suspect that the neglect to do this is the reason why some statements made by other writers on this subject differ materially from my own. If the cleavage be well developed, it is best to select specimens in which it is at right angles to the plane of stratification, since then there is less fear of confounding together the original and the superinduced structures. In any case the angle of their intersection should be known. It is desirable to prepare sections at right angles to the cleavage, both in the line of its dip and in that of its strike, since in many cases there is as much difference in the structure in these two directions as between a slate with very perfect cleavage and one with a much less perfect. It is, however, still more important to prepare also sections in the plane of cleavage, since the general appearance of a section thus cut may be so very different to that from one at right angles to the cleavage, that any one might easily mistake it for a section of a totally different rock.

When, nearly thirty years ago, I commenced the study of the microscopical structure of slates, especially in connexion with their cleavage, I was struck with the remarkable difference between the constitution of many so-called *clay*-slates and modern deposits of true clay. I found that in some slates the relative amount of very fine granular material analogous to kaolin was very small, whilst that of mica, or some closely allied laminar mineral, was very large. This does not occur in plates of considerable size, like the mica in many stratified rocks, but mainly in the form of flakes so minute that in the best Welsh slates their average size may be taken at $\frac{1}{2000}$ of an inch broad, and $\frac{1}{6000}$ of an inch thick, whilst many are considerably less; separately they are altogether invisible to the naked eye, and at most only serve to give a silky lustre to the rock when they lie chiefly in the plane of the fracture.

Since it is a point of much importance, it appears to me desirable to state clearly what is the evidence in favour of these conclusions. The structure is best seen in black slates, like some near Llanberis, since the immense number of red grains in purple slates interferes with accurate observations. When a section of this black slate, cut at right angles to the cleavage in the line of the dip, is examined with a power of about 250 linear, we can clearly see that the great bulk of the rock is made up of what look like transparent fibres, which, so far as the mere appearance of this one section is concerned, might be either needles, like hornblende, or transverse sections of laminæ, like flakes of mica. The greater part of these lie nearly in the plane of cleavage; but some are inclined to it at a more or less considerable angle. Amongst these flakes or fibres occur objects which look like extremely fine black hairs, their thickness being often less than $\frac{1}{50,000}$ of an inch, which, however, so far as this appearance is concerned, might be transverse sections of thin plates. A section cut in the line of strike differs only in showing that the needles or laminæ lie less completely in the plane of cleavage. Of course, if the objects which appear to be fibres were really needles, like those of hornblende, we should also see them of similar form in a section cut in the plane of cleavage, and they would depolarize light as strongly as before; whereas, if they were laminæ of mica, they would show no well-marked outline, because the flakes would lie one over the other, and they would scarcely depolarize, because the light would pass through them in the direction along which there is little or no double refraction. Now, when we examine a section of the above-named black slate so cut, we do see, as before, the small black hairs, which therefore must really be needles; but at the same time we clearly see that the colourless main constituent of the rock must be in the form of flat plates, as truly laminar as mica, since no more of apparently needle-shaped form are visible than correspond to the transverse sections of those laminæ which are inclined at a more or less considerable angle to the plane of cleavage. The difference in the appearance is, in fact, analogous to that seen in sections of mica-schist cut at right angles and parallel to the foliation. The result of this structure is that a well-cleaved slate of this type depolarizes like a uniaxial crystal having the principal axis perpendicular to the cleavage.

It is quite possible that some much more modern deposits in other parts of the world may have the same structure as these slates; but I have not met with any in our own country more recent than the Devonian. It is, however, not merely a question of age, since some of the strata of our Silurian and older rocks have a constitution similar to that of modern clays. Whatever may be the true nature of this colourless laminar mineral, its optical characters closely correspond to those of mica, and it has a far stronger depolarizing-power than chlorite. I am inclined to believe that the black hair-like crystals are magnetite. For a long time I thought it probable that the micaceous mineral had been formed *in situ* by an alteration of partially decomposed felspar, so that the rock might be looked upon as analogous to the pseudomorphs of chlorite or talc already described. Such a crystallization of mica has most unquestionably occurred in some of those fine-grained slaty-looking rocks which are a connecting-link between slates and schists; but the resulting structure is very different from what I look upon as typical of true slates. When thus formed *in situ*, the crystals of mica are not stratified, but lie at all possible azimuths, and, moreover, have collected about special centres; so that the structure is very far from uniform, and more analogous to that of a concretionary than to that of a bedded rock. On the contrary, in typical slates there is an almost complete uniformity in a horizontal direction along each thin bed, though each may differ much vertically from its neighbours in the relative amount of the different constituents, even when the layers are as thin as paper. The whole structure is, in fact, just such as would result from the deposition of material sorted by gentle currents, and subsequently compressed vertically by the pressure of overlying strata, or laterally by that which gave rise to slaty cleavage. At the same time it appears to me equally certain that laminar minerals of the chlorite or talc groups have been formed since the deposition of the rock, and crystallized *in situ*, without materially altering the general structure. Some thin bands, and perhaps even thicker beds, are indeed exclusively composed of these more recently formed minerals; but the development *in situ* of hydrous silicates is a very different thing from the crystallization of the mica. For these reasons I am disposed to think it far more probable that the principal, typical, micaceous constituent of the slates now under consideration was derived from the disintegration of an older rock, and that the difference between what we may call kaolinitic and micaceous clay-slates depended on the constitution of the rocks which furnished the material. Felspathic felsites and coarse-grained granites, even when very micaceous, could yield only kaolinitic clays; whereas the fine-grained micaceous felsites already mentioned could yield, and, as I think, have yielded, the material of the micaceous clay-slates. In them the mica exists in such small particles that it has not been separated from the kaolin, whereas in the case of granites the plates of mica, being comparatively very large, chiefly remained associated with the quartz, and gave rise to micaceous sandstones. Perhaps some minor difficulties may remain; but this supposition will ex-explain the principal facts in a very satisfactory manner. As an excellent illustration of this subject, I will describe some of the slate rocks of North Wales.

Slate Rocks of North Wales.

In order to learn the source of the material of the fine-grained beds, it is obviously best to study such a coarse-grained deposit as that met with in a small quarry at Felin Cochwillin, Bethesda, near Bangor. In this rock the constituent fragments vary from $\frac{1}{10}$ to $\frac{1}{100}$ of an inch in diameter. I presume that most geologists would call it an ash bed; but at the same time I think that no simple examination of the rock in its natural state would suffice to decide whether it was a true ash or formed of the detritus of igneous rocks. Careful microscopical examination does, however, show that it was in all probability a true felsitic ash, since the grains are not as though formed by the mere breaking up of a solid rock consolidated under pressure. Some of the fragments are an imperfect pumice; and the crystals of felspar and the fragments of the felsitic base often contain as perfect empty, more or less spherical, bubbles as bad artificial glass. The quartz grains also appear to have been derived from a quartz-felsite, since they not only have the characteristic crystalline shape and internal structure of such quartz, but occasionally are attached to or enclose portions of the felsitic base. The structure of this base varies considerably in different fragments, but corresponds closely with that of the various massive felsites found in the district. Sometimes these are simply felspathic, but usually contain a large amount of a micaceous mineral, easily recognized by its shape and optical characters. The amount of granules and needles of magnetite or ilmenite varies much, even in different parts of the same fragment. Occasionally we see black grains of basalt, and sometimes fragments of what may have been augite altered into a deep-green laminar mineral, which we may call chlorite, quite unlike the mica in the felsites. Judging from analogy, the associated augite or olivine was probably the source of the more considerable amount of the same green chloritic mineral which fills the cavities in the imperfect pumice and the interspaces between the constituent fragments of the whole rock. It has also to a slight extent penetrated into the felsitic fragments, and appears to have partially replaced the felspar; so that some fragments may be looked upon as imperfect pseudomorphs. A few grains may have been derived from an older slate; but yet, on the whole, I think we ought to regard the rock as a consolidated quartzose felsitic ash.

If the micaceous basis of this ash were worn down in the crater into dust, or more completely decomposed by weathering, and the material afterwards sorted by gentle currents of water, it would yield a deposit corresponding in all essential particulars with the fine-grained slates of Penrhyn and Llanberis, allowance, of course, being made for subsequent chemical and mechanical changes. Thus, for example, several different laminar chloritic or talcose minerals have crystallized out, not, as in the coarse-grained rock, only in the cavities, but have pushed aside and displaced the surrounding material. Vast numbers of small red crystals of specular iron or very minute black needles of some other less-oxidized iron mineral have been formed *in situ*; whilst occasionally calcite and quartz have been deposited in crystals of some size or disseminated through the rock, so as to greatly increase its solidity. The structure has also been much altered by the pressure which gave rise to cleavage.

Other beds in the same group of rocks differ very widely from those just described, and contain little mica and much material analogous to kaolin, as though either derived from the decomposition of ash or rocks containing much less mica and more felspar than that which yielded the material of the Penrhyn and Llanberis slates, or separated from the more micaceous material by currents.

It is perhaps scarcely needful to say that when I speak of the material having originated from any particular kind of rock, I mean that it did so in the *first instance*. It by no means follows that it was so derived *directly*, and was not previously deposited and again broken up, before being finally accumulated in the rocks in which we now find it.

Development of Slaty Cleavage.

Whilst now treating on the structure of the fine-grained slates, it will be well to consider some facts connected with cleavage which until quite recently have been a great puzzle to me. As I pointed out in various papers published many years ago, the structure of well-cleaved slates, like those of Penrhyn, may be easily explained by supposing that the ultimate particles of mica were originally inclined in a nearly uniform manner in all directions, and were subsequently rearranged by lateral pressure, so as to lie more or less completely in the plane along which the rock yielded as a plastic substance. There is so much independent proof of pressure having acted in the direction and to the extent necessary to explain all the various phenomena, and the mechanical theory of cleavage is now so generally accepted, that it may perhaps be thought superfluous to support it by further facts. There was, however, always this difficulty, that I had never found any uncleaved slate-rock having *now* the exact structure which I assumed that the cleaved rocks had originally; and in endeavouring to gradually trace back the structure of slates having a very perfect cleavage to those having none, I did not find, as I anticipated, a gradual passage, but such an apparent break of continuity as to lead me to conclude that there are *two* distinct types of cleavage—one due to the arrangement of the ultimate atoms when the rock yielded as a plastic substance, and the other due to very close joints when it yielded by fractures like a partially rigid substance. More careful and detailed examination of other specimens, however, has convinced me that, though in some cases my original explanation of very perfect cleavage may be true, yet very often the two kinds of structure are only different stages of one process. Thus, for example, some of the undisturbed parts of a very imperfectly cleaved slate from Liskeard show very clearly that the original structure was merely fine lamination in the plane of deposition, nearly all the minute flakes of mica lying in the plane of stratification. These beds are of such extreme thinness that occasionally they are only $\frac{1}{1000}$ of an inch in thickness. In some parts they have been squeezed by lateral compression into contortions similar to those often seen on a large scale, only so small that they are invisible to the naked eye. When magnified about 100 linear, the general appearance is as shown by fig. 3.

It is obvious, however, that such a rock could yield in this manner only to a very moderate extent without the contortions breaking and the detached portions moving one over the other, so as to give rise to a system of approximately parallel planes of discontinuity, or close joints, as shown by fig. 4, which also is magnified about 100 linear. These are similar to those which may be seen so well in the mica-schist on the shore of Loch Lomond, not far south of

Tarbet; only they are on a scale about $\frac{1}{50}$ as large, and therefore the rock appears to have an imperfect cleavage throughout rather than a jointed structure. Here, then, we have an imperfect cleavage due to the lateral yielding of a rock composed of material not truly plastic in its ultimate constitution.

Fig. 3.—*Slate, Liskeard, with minute contortions.*

Fig. 4.—*Slate, Liskeard, with planes of discontinuity.*

Fig. 5.—*Slate, Shap, disturbed by pressure.*

Fig. 6.—*Slate, Llanberis, with well-developed cleavage.*

The peculiar laminated structure of this Liskeard slate appears to have favoured the production of this close-jointed structure, and the joints are still further marked by the subsequent introduction of black oxide of iron; but in some cases, as in the pencil-slate of Shap, the flakes of mica which constitute nearly the whole of the rock have been thrown out of their original position in a similar manner to the contorted material of the Liskeard slate, often without the formation of definite contortions or joints, as shown somewhat diagramatically by fig. 5, magnified about 200 linear.

We thus arrive at a structure in which the flakes in each minute broken portion do lie in the plane of stratification, but this plane is so contorted and broken up, that, as seen in a section cut at right angles to both bedding and cleavage, they are nearly equally inclined at all azimuths. The amount of the lateral yielding of the mass necessary to give rise to this structure is apparently small compared with that which has certainly occurred in the case of many well-cleaved slates; but it clearly shows how the particles may soon become so arranged that the further yielding of the rock would totally efface all evidence of the first stages of the process, and cause the constituent laminæ to become approximately parallel to one plane, as shown, somewhat diagramatically, by fig. 6, magnified about 200 linear.

I have thought it very desirable to call attention to these facts, since I think the explanation I have given removes a very serious difficulty in completely explaining the mechanical origin of slaty cleavage in rocks which have yielded to pressure as imperfectly plastic substances.

Slates of the English Lake-district.

It would be difficult to find a better illustration of the influence of the mineral constitution of the original material on the final nature of more or less altered stratified rocks than is furnished to us by comparing the green slates of Cumberland and Westmoreland with those from Wales already described. It is, I suppose, agreed on by all of us that they were to a great extent derived from volcanic ashes; but no mere examination of the rocks in their natural state would lead any one to imagine that the microscopical proof of their true volcanic nature was so perfect. At the same time this method of study proves equally well that often such great changes have subsequently occurred that very little of the original material can now be seen, and the character of the altered deposit closely approaches that of a rock solidified from fusion.

It would be interesting to ascertain the distribution in time and space of the scarcely altered and greatly changed rocks; but, unfortunately I can indicate this only in a very incomplete and perhaps incorrect manner. The general appearance, even of the two extremes, is not so different as to attract attention at once; and it was only by careful microscopical investigation that I became aware of the existence of any considerable alteration. Those of my sections which show the least change are all from Langdale and Rydal. At Ambleside, Troutbeck, and Smethwaite Bridge there is more alteration; whilst at Keswick and Rosthwaite it is much greater, and sometimes so very great that all direct evidence of the original nature of the rock has been obliterated.

1. *Rocks little altered.*—My best specimens of comparatively unaltered material are from Langdale; and I would especially describe one of somewhat coarse grains, containing fragments varying up to $\frac{1}{10}$ inch in diameter. This, to a great extent, is composed of what may be called very vesicular lava or imperfect pumice, the basis of which varies from perfect glass to a completely devitrified felsite, and often shows a perfect fluidal structure. This glassy material is transparent and of pale green colour, and still remains so when partially devitrified by the formation here and there of material which depolarizes light, but yet shows no definite crystals. The next stage is the formation of small dark grains of magnetite or ilmenite, and well-developed felspar microliths; and the final stage of devitrification consists in the passage of the remaining glass into granular matter, so as to give rise to a sort of felsite. Scattered through the glassy or stony basis are larger crystals of felspar; and the deposit contains many detached more or less broken crystals of the same, which often enclose portions of the

green glass. On the whole it would be impossible to meet with a better illustration of an ash due to a more or less glassy felspathic lava. Quartz appears to be absent from this particular specimen, except as filling up a few cavities; and unless it be in the form of minute needles, met with here and there in the glassy basis, augite does not occur. To this circumstance may be attributed the very small amount of green material subsequently formed in the rock. In some other specimens grains of quartz do occur; and it is interesting to find that the cavities sometimes contain no liquid, which probably has been driven off by heat, in the same manner as from grains of sand in the stratified deposits in contact with the erupted rocks of Salisbury Crags, described further on. In other localities the ash must have contained a much more perfect pumice, and in others a considerable amount of augite, subsequently altered into a green fibrous mineral, which also entirely or partially fills what were originally cavities in the rock. Sometimes, even in the same microscopical section we can trace a gradual passage from ash composed of particles large enough to be easily recognized, to what appears to have been an extremely fine-grained volcanic dust, associated with fragments of true pumice. At Ambleside some comparatively large fragments of pumice occur, with their cavities filled with calcite, in an otherwise fine-grained slate, in the same manner as they so often occur in fine-grained oceanic mud. This, of course, is easily explained, since their unusual buoyancy would enable them to float where denser fragments could not be drifted.

2. *Rocks more or less considerably altered.*—Passing from cases where the original nature of the material is sufficiently well shown, we come by degrees to others in which it has been more or less changed since deposition, until we arrive at cases in which it is difficult or impossible to decide from the structure alone whether the rock was erupted and subsequently changed by water, or was an ash of similar material afterwards changed by water and heat. There appears to be no doubt that certain minerals have been formed *in situ*, such as epidote and the various green substances described further on, and also no doubt that the augite, much of the felspar, and the garnets were original constituents of the ash; but it is sometimes difficult or impossible to say whether the felspar microliths were or were not formed *in situ*. On the whole it is most probable that those met with in some specimens were deposited as ash, whilst those in others were due to subsequent alteration.

The first stage in the alteration was probably the filling-up of cavities and the spaces between the particles with calcite, quartz, and hydrous silicates, so as to consolidate the rock. This change may, I think, be referred to the decomposition of the augite and other unstable materials of volcanic ash, and might not require any materially elevated temperature. The formation of felspar and epidote was doubtless greatly favoured by the very imperfectly decomposed condition of the original material, but probably required a more elevated temperature.

Cleavage in the Green Slates.

In studying the green slates, to try and learn the nature of the original material, it is very desirable to examine specimens which have little or no cleavage. When the rock has been greatly compressed, and a perfect cleavage developed, the structure of the constituent fragments has been so much changed that it is almost impossible to say what they originally were. Thus, for example, the brecciated slates of Rosthwaite suffice to establish beyond all doubt the mechanical origin of the cleavage; but the fragments are so compressed in the plane of cleavage that it is impossible to be sure whether the greater part were felsite or an older slate. There does, however, appear to be sufficient evidence to prove that they contain not only fragments derived directly from volcanic ash, but also others which, if originally of similar nature, must have been stratified, consolidated, altered, and broken up again, perhaps during volcanic outbursts, and not necessarily portions of rocks of much higher antiquity than the main mass of the slates.

Slates in Different districts.

Having now, as I think, proved that we must not seek for true representatives of some of our slate rocks amongst more modern British deposits, it will be well to consider the general character of some of our older rocks. Judging from what I have been able to ascertain from those districts which I have more completely examined, little reliance ought to be placed on conclusions drawn from a very limited number of specimens; for considerable variation may depend on local sorting; and what I am now able to state respecting some other districts must be looked upon as provisional, and possibly only partially true. I have had considerable difficulty in reconciling my own observations with those of some who have treated on this subject. Possibly this may be due to actual differences in the slates of different districts, but may also be due to a difference in the methods of observation, leading us to a difference of opinion respecting the true shape and nature of the constituent particles. Some of my conclusions may be wrong, since occasionally it is extremely difficult to ascertain what is the truth. I now give solely the results derived from my own examination of specimens collected and prepared by myself.

I may here point out that the general optical character of a fine-grained slate consisting mainly of mica, differs very greatly from that of a more normal deposit. When a section cut at right angles to the cleavage is rotated in polarized light, it becomes, over nearly the whole surface, very bright and much darker at different azimuths, like a doubly refracting crystal, whereas there is little or no such change in the case of true *clay* slates of the normal granular type, containing much kaolin and very little mica.

The only specimen of slate from the Loch-Awe district that I have examined is of perfectly normal type, but is so much altered that it is really a fine-grained schist.

The slate of Birnam closely corresponds with that of Penrhyn, and is mainly an abnormal fine-grained micaceous deposit.

Some of the rocks in the district of Moffat are of the usual granular type; but others are highly micaceous, and in one specimen I have found a little pumice and what appear to have been fragments of glassy fibres like the so-called "Pélé's hair." This glassy material constitutes, however, only 3 or 4 per cent. of the volume of the rock.

Passing to the English Lake-district, the slate of Portinscale is of the normal granular type; but rocks of very similar age not far from the granite on Skiddaw Forest are, as is well known, greatly altered. The original material is almost wholly changed into crystalline minerals developed *in situ*, amongst which hornblende and chiastolite are the most characteristic.

Near Windermere the slates above the Coniston Limestone are also of the normal granular type; but possibly there are considerable local variations, since the pencil-slate of Shap is almost wholly micaceous.

As already mentioned, the slate-rocks in North Wales similarly vary very greatly in different beds and localities; and, as far as I have been able to ascertain, the same remark will apply to those of Devon and Cornwall.

We may thus, I think, consider it proved that the original mineral composition of our older stratified rocks varied greatly, though much remains to be learned respecting the horizontal and vertical distribution of the different types. Even when théy really differ much in constitution, the general appearance of the finer-grained varieties is not strikingly different; and the presence or absence of cleavage still further obscures the difference. An observer might thus easily overlook variations which might be of very great importance in connexion with metamorphism. It appears to me that the development or absence of certain minerals in metamorphic rocks depended as much on the original nature of the material as on any mere difference of the temperature to which the rocks have been exposed; so that lower-lying rocks might very well be less altered than those above them, even though probably at one time exposed to a higher temperature, invading them from below.

General Changes after Deposition.

The development of such minerals as pyrites in stratified rocks is so well understood that I need not occupy time in saying any thing about it, and will confine my remarks to what may be called stony minerals.

If a stratified rock consisted of material which was thoroughly decomposed by weathering into stable products, it is clear that, when further exposed to water and carbonic acid, no considerable change could occur at the normal temperature, though it might be consolidated by the introduction of soluble minerals. On the contrary, if the constituents of the deposit were in a state of unstable equilibrium, like those in fresh volcanic ashes, it is equally clear that great subsequent changes might be expected. Thus, for example, in a section of consolidated peperino from Vesuvius, I find that the fragments of augite have been altered into a new substance, and the cavities in the ash more or less completely filled with a fibrous mineral with feeble double refraction and having the negative axis of depolarization in the line of the fibres. My belief is that this is some hydrous silicate—perhaps a zeolite; but at all events its formation has thoroughly hardened the whole deposit, and given rise to a greater change in the structure than is met with in many rocks of remote geological epochs.

An almost colourless crystalline mineral has also been developed in some of the mud from 2230 fathoms in the South Pacific. It is insoluble in strong hot acids until after it has been boiled in caustic potash, and is probably a silicate. It occurs in small crystals, which have been deposited in radiate groups on the surface of many of the sand-grains. The mud also contains many fragments of an apparently basic lava, more or less completely altered into a sort of palagonite; and probably the crystalline mineral was a product of this change.

Some specimens of our gault, when washed, yield analogous radiating groups of a transparent mineral insoluble in acids.

Another silicate very commonly found in stratified rocks is glauconite. According to Ehrenberg it occurs inside the cells of Foraminifera in some recent deposits; it is at all events well seen in many of our older rocks. I have studied it more particularly in the harder bands of the Barton Clay, in the firestone of Ventnor, in the Kentish Rag, in the Greensands, in Lias, and in some other rocks. It is often found filling the cells of Foraminifera, the central hollow and minute tubes in the joints of *Pentacrinus*, the open spaces of corals, holes bored into shells, open spaces left amongst crystals of calcite when aragonite shells became crystalline, and what were probably minute borings present in the deposit at the time of its formation; in fact, it may be said to fill up cavities of all kinds. In some few cases it appears as if it had crystallized out independent of any cavity; but often there is no positive evidence of how it was formed.

As far as I have been able to ascertain, glauconite consists of more or less irregular and imperfect scales, having the negative axis perpendicular to their surface. Usually these scales are extremely minute, and are arranged in no definite order; but occasionally they are larger, sometimes arranged in a radiate, and sometimes in a concentric manner. It is very curious to see in the sections of some rocks how the grains of glauconite have been crushed by pressure, though the fragments still remain scattered about in close proximity.

Since glauconite is known to occur as a product of the alteration of augite and hornblende, and since in the cavities of some altered dolerites I have found a green substance having exactly the same characters as the glauconite of the Greensand, it would be a very simple explanation to suppose that it had been formed out of the augitic or hornblendic constituents of the deposit. I am by no means certain that some of the grains are not really pseudomorphs; but at the same time the amount of glauconite in some beds of the Greensand is far too great to allow us to suppose that it was to any considerable extent formed directly, *in situ*, from augitic or hornblendic sands. In some cases I am inclined to think that the grains were formed elsewhere, and drifted as sand into their present position. On washing different specimens of Greensand I was also much struck with the manner in which the glauconite seemed, as it were, to replace yellow ferruginous mud, as if it had been to some extent formed out of it. On the whole, then, we have evidence of considerable variation in the conditions; but yet all the facts agree in showing that glauconite was formed by concretionary aggregation at the time of deposition, or very shortly afterwards, from material closely related to decomposed augite, hornblende, or olivine.

There is far better evidence of the direct formation from augite of green minerals more or less closely allied to glauconite, in the green slates of the English lake-district. I may here say that, according to my own observations, the augite and olivine of our older volcanic rocks occur altered into at least three different kinds of green material. One of these corresponds closely, if not absolutely, with glauconite, and is composed of laminæ; another is composed of fibres; and the third is either amorphous or belongs to the regular system, unlike the others, not depolarizing. All these three substances also occur in what must have been cavities in the rock, into which no doubt they have been introduced by the agency of water. The fragments of augite in the Cumberland green slates have been changed, and the cavities filled, in the same manner. On the whole, the fibrous substance is the most abundant, and is characterized by having its positive axis of depolarization not strictly parallel to the line of the fibres, as though the mineral might be some variety of asbestos. It fills the cells of fragments of pumice, and also larger cavities, formed, like those in peperino, by the evolution of gas amongst the unconsolidated mud, or by contraction during consolidation. Since the identification of the true nature of fragments of pumice is a matter of much interest, I give fig. 7 (p. 80) as an illustration of their general character, which represents one magnified about 100 linear. It must have been just like those so common in deep-ocean mud. The original walls of the cells are about $\frac{1}{8000}$ of an inch thick, and are now partially, if not wholly, devitrified; and the empty cells are filled with the green substance already named, just as the cells of Foraminifera in more recent rocks are filled with glauconite.

Though there are several quite distinct kinds of these green minerals, which possibly differ in composition, yet they form a very definite group; all occur under similar circumstances, and often intimately associated. On comparing different specimens of slate we can see that those in which their amount is greatest are, as a rule, those which originally contained the most augite or olivine in the ash, as shown by the pseudomorphs.

Fig. 7.—*Fragment of pumice filled with a green mineral.*

Fig. 8.—*Small concretion in the Slate of Birnam.*

I have endeavoured to find out the true relations of all the different green or analogous colourless minerals so often developed in slates since their deposition; but though it is quite easy to distinguish several, and to recognize each well enough in other specimens, I must say I feel much hesitation in identifying them with known minerals. We should not, however, be far wrong if we regarded the whole group as evidence of the same general physical conditions, and the production of each particular kind as evidence of some difference in the chemical composition of the material. This appears to me well established by what may be seen in some of the fine-grained slates. Thus, for example, in the slate of Birnam, near Dunkeld, small elongated concretions have been formed along the planes of cleavage, as shown (magn. 150 linear) by fig. 8. These are composed of alternations of two very distinct laminar minerals. One is colourless, with a depolarizing power several times greater than that of quartz, the negative axis being perpendicular to the laminæ; whilst the other is deep green, very dichroic, has a very weak depolarizing power, and gives with polarized light a remarkable copper-colour, not corresponding with any interference tint. In the slate of Penrhyn we meet with similar but shorter concretions, composed of a mixture of the above-named colourless mineral (which may be talc) with one that is green and dichroic, with a depolarizing power much weaker than that of quartz, having the positive axis perpendicular to the laminæ, and further differing from the analogous mineral in the Birnam slates in giving perfectly normal though low interference tints. According to Dana, similar mixtures are met with in larger crystals of minerals belonging to the same general group as those now under consideration. I presume that we shall all agree that the production of such minerals indicates the more or less prolonged action of water. I do not see any need to assume a high temperature; but I must say that it appears to me that their production is evidence of the preexistence of material corresponding to more or less decomposed augite, hornblende, or olivine; and I think that the presence or absence of such products depended more upon the original nature of the material than upon any thing else.

Metamorphic Rocks.

The above-named facts naturally lead me to the question of metamorphism. If we had to deal with such extremes as shale and schists, we could not hesitate as to the use of the term *metamorphic*; but, as so often happens, one extreme condition passes so gradually into another that it is difficult or impossible to draw a boundary line. I must say that I feel quite unable to offer such a definition of metamorphism as would agree with the microscopical structure of the rocks, and satisfy the requirements of field-geologists. If its original constituents have been entirely recrystallized into new minerals, especially into quartz and anhydrous silicates, it seems quite reasonable to call a rock metamorphic; but such a definition would include many rocks which are usually called slates, simply because no such complete recrystallization can be detected by the naked eye. On the contrary, many schists, which are always called metamorphic, do, as I believe, sometimes contain material which has been little, if at all, changed; so that the prevalent definition of metamorphism seems to depend more on general external appearance than on internal structure. However, instead of occupying time in discussing names, it will be far better to consider a few points which appear to deserve special attention. The entire question of metamorphism is far too wide to be dealt with on such an occasion as the present.

Artificial Metamorphism.

I much regret that I am unable to refer to more than one illustration of metamorphism produced artificially. This is a specimen of slate kept long at a high temperature by our late, lamented friend David Forbes. Unfortunately I do not know the exact nature of the rock before it was changed; but it is quite clear that the heat has actually fused some portions and converted them into what may be called slag, without having so far melted the whole as to obliterate the original stratification. In the fused portion needle-shaped crystals have been developed, which have the general characters of the pyroxene found in some artificial slags, as well as others which correspond with felspar. It is therefore quite unlike any true natural metamorphic schist, but still is of interest as showing what characters are due to crystallization *in situ*; and the newly-formed minerals closely correspond with those found in some rocks metamorphosed naturally. The main difference seems to be that the natural rocks were not actually fused like a slag, and, being under great pressure, a certain amount of liquid water was present, which greatly facilitated the transference of the constituents from one part of the rock to another, and the development of certain minerals like quartz, mica, hornblende, and calcite.

Local Contact Metamorphism.

As an illustration of a few special facts, I select the sandstone and shale of Carboniferous age in contact with the igneous rock of

Salisbury Crags. One point of interest is, that although the grains of sand contain many cavities which no doubt, as usual, originally contained water, they have all lost it, as though it had been expelled by the heat of the igneous rock, in the same manner as it is easily expelled from unaltered quartz by a high artificial temperature. Independent of this, the quartz sand is very little, if at all, changed. Not so, however, the calcareous shale, which has, to a great extent, been altered into a mass of small, nearly colourless, prismatic crystals having the form and optical characters of tremolite, or of the pyroxene met with in some slags. This often occurs in small nests along with calcite and quartz, all crystallized *in situ*. The whole rock, however, is of such fine grain, that to the naked eye it appears to be only hardened. Though the general structure is very different from that of hornblende-schists, this rock is of considerable interest in connexion with them, and also as affording good evidence of exposure to a somewhat elevated temperature.

Development of Mica-schist.

I have taken much pains in studying the gradual formation of mica-schist from unaltered slates. Apparently the various steps in the change are not always exactly the same; but, as far as I have been able to learn from the material at my disposal, the order of change was somewhat as illustrated by the following examples:—

1. A slate close to an igneous rock near Liskeard is composed of thin beds of the usual granular kaolin type, with but little mica, alternating with others of the mica-slate type, containing but little granular matter. Now, in the midst of these materials, evidently deposited as such, there have been formed detached scattered concretions, about $\frac{1}{500}$ of an inch in diameter, composed of mica and quartz crystallized *in situ*, in grains which are on an average somewhere about $\frac{1}{2000}$ of an inch in diameter. These little concretions are, in fact, the very germs of mica-schist, if I may be allowed to use such an expression. An obliquely transverse vein contains larger crystals of mica and quartz, thus clearly proving the transfer of such material from one part to another.

2. The black chiastolite slate of Ivy Bridge shows some valuable facts. The concretions are larger than those just described, and consist more exclusively of mica. They show only obscure traces of the stratification passing through them; but it is very distinct in the surrounding material, which has not crystallized *in situ*. The segregation of mica is well shown, not only by a somewhat transverse vein, but also by the alteration of the chiastolite. The altered crystals have a sharp outline, and, with ordinary light, are colourless and transparent from the central cross of impurities up to the extreme edge; but when examined by polarized light they are seen to be pseudomorphs. The outside, for some depth inwards, has been changed into mica, often with its laminæ perpendicular to the surface; and the centre no longer has the strong

depolarizing power of unaltered chiastolite, but has been changed into an isotropic substance not yet identified. We thus see very clearly that the rock must have been exposed to such conditions that mica, as such, or its constituents could wander about from one point to another and collect round special centres.

3. *Slate near Granite at Wicca Pool.*—This furnished me with a most instructive series of specimens. In one the mica and quartz have segregated in the manner just described; only, in place of being detached, the concretions have grown so much that they have often coalesced and thrown the residual material into irregular darker patches, where it has to a considerable extent crystallized into a dirty-greenish-brown isotropic mineral, which I have not been able to identify, unless, indeed, it be garnet, which is doubtful.

From such a specimen we gradually pass to cases where this mineral has been thrown off and collected, not so much into irregular patches as into small thin lenticular masses lying, roughly speaking, in the plane of stratification, so as to produce a true foliation. Here and there are also lenticular masses of quartz, crystallized *in situ*, in grains varying up to $\frac{1}{100}$ of an inch in diameter. In a third specimen this kind of foliation is still more perfectly developed, and the isotropic mineral is, to a considerable extent, represented, if not actually replaced, by mica of darker colour than that in the rest of the rock; and, in fact, here and there it almost disappears. In a fourth specimen the isotropic mineral appears to be absent, and the rock is composed of quartz and of very dark and colourless mica, all crystallized *in situ*. In some parts of the thin section the material was apparently uniformly stratified in well-marked thin beds, and there are no transverse cleavage-joints. Here the crystals of mica lie, to a great extent, more or less parallel to the plane of stratification. That they were not deposited in that position as mud, however, is well shown by the structure of other parts of the section, where the rock had given way to lateral pressure by the formation of close, irregular, roughly parallel joints, in the manner described when treating on cleavage. Here the crystals of dark mica lie along the joints, in the same manner as they occur in the detached transverse cracks in specimens of altered slate from Liskeard and Ivybridge; so that we have a good illustration of one particular type of cleavage-foliation, more highly developed in some of the coarser-grained mica-schists described further on.

Another type of imperfect cleavage-foliation is when the crystallization is modified by the presence of a true, well-developed, structural cleavage. The slate of Birnam, already described, is an illustration of this; for in it we see that lenticular portions of the green laminar mineral have been formed in the plane of cleavage; and in the thin beds which contain much of this mineral we have a perfect, true cleavage-foliation, in which the laminæ lie in the plane of cleavage. A similar but finer-grained structure occurs in a few of the green slates of Westmoreland.

Fine-grained Schists.

It will thus be seen that in the rocks just described we have a gradual and perfect passage from an almost normal slate to what is practically a true mica-schist, with stratification-foliation or cleavage-foliation. The only essential difference between the more altered specimens and the most typical mica-schists is that the crystals are less, being, on an average, only $\frac{1}{10}$ as large. There are, however, many beds amongst the Highland schists which are of very little coarser grain than these altered slates. As far as I can see, we have a real and perfect passage from slate to schist; and the more altered varieties from Wicca Pool do not differ from the most typical schists in any more essential particulars than pebbles differ from boulders.

Rocks which are thus practically fine-grained schists differ so little from true unaltered slate in general appearance, that probably they have often been mistaken for slates. At all events, I know that I must have many times made this mistake myself, which has prevented me from being able to say any thing very definite respecting the horizontal distribution of the altered and unaltered rocks. I regret that I cannot decide whether it is in all cases merely a local change, or sometimes very general over a considerable district.

Foliation in slightly altered Slates.

On the whole, then, these connecting-links between slates and schists clearly show that foliation is essentially different from either stratification or cleavage. In my opinion they prove that it is the result of the varying segregation of different minerals, controlled by various previously existing structures. It will be well to consider some questions more fully when discussing the structure of true schists; but I think it would be impossible to give a better illustration of my meaning than the case of some concretionary limestones. In these the facts seem to show very clearly that the material was originally deposited in a pretty uniform condition; but the carbonate of lime has collected in more or less lenticular masses, or filled transverse fissures to form veins, and left a great part of the non-calcareous deposit as a laminated shale wrapping irregularly round the concretions. On the whole such a rock may be truly stratified; but the details are not true stratification. So, in the case of these altered slates, the existing structure is due to irregular segregation, controlled by the previously existing structure, whether it was stratification, close joints, or true cleavage. We might very well draw the same conclusion from the study of true schists; but then it would be, to a considerable extent, more a matter of inference than of proof, whereas in the rocks now under consideration both true stratification, close joints, true cleavage, and true foliation are present to such an extent that their mutual relations are easily seen.

Structure of Schists.

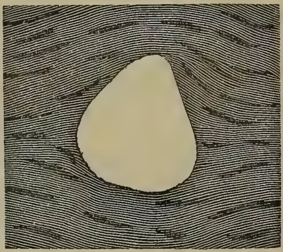
It thus appears that we may trace, step by step, the change from stratified deposits of a more or less normal type to rocks in which nearly the whole of the material has recrystallized *in situ*, to form truly metamorphic schists; but, at the same time, it does not necessarily follow that all schists which have crystallized *in situ* were originally composed of sand and clay. I therefore now propose to examine what evidence still remains of their truly detrital origin, and of their probable constitution before crystallization took place. I scarcely need say that no class of microscopical rock-preparations are more difficult to make than sections of some mica-schists, cut at right angles to the foliation. By slow and careful grinding, and by repeatedly covering the surface with Canada balsam and heating until it became hard, so that it might penetrate between the plates of mica and bind all together, I have, however, succeeded in preparing faultless sections of the most intractable specimens, which can be examined with as high magnifying powers as are necessary for their efficient study.

Presence of the Original Sand and Mud in Schists.

In my paper on mica-schist, published many years ago in our Journal (vol. xix. p. 401), I described what I looked upon as the original grains of sand still visible in the altered rock. I have lately reexamined my microscopical sections with improved apparatus, and am now more convinced than ever that I was correct. The best way of studying this question is to use a $\frac{2}{3}$ inch object-glass with an attached, parabolic, side reflector, in such a manner that the object may be seen at will, either by surface-illumination or by transmitted polarized light. When quartz from various sources is thus examined, some appears quite transparent and colourless by transmitted light, and almost black by surface-illumination, whilst some is more or less opaque by transmitted light, and milk-white by surface-illumination. A good deal is intermediate between these extremes, or shows a mottled mixture of both. The whiteness is either of a granular character (when due to fluid-cavities or large granules), or uniform and homogeneous (when the foreign particles are too small to be separately visible). Some specimens are further characterized by the presence of many included hair-like crystals.

The quartz of many specimens of schist appears almost wholly dark by surface-illumination; but here and there, in certain specimens from Dunkeld and Arroquhar, are milk-white grains, perfectly unlike the surrounding quartz, having a well-defined, rounded, waterworn, or more angular outline, just like the genuine and undoubted grains of sand in more recent, unaltered, stratified rocks. They further differ from the quartz of the schist itself in having a simple optical structure, each being a part of a single crystal, like most grains of sand; whereas the small aggregations of quartz crystallized *in situ* have a complex structure, and are made up of many small interfering crystals. Occasionally some of the surrounding clear quartz is in crystalline continuity with these grains; but usually it has crystallized independently, probably because the grains were originally completely surrounded by deposit, and not by the empty spaces which existed in the case of the consolidated sandstones with deposited quartz, already described. As an illustration of one of these grains, I give fig. 9, magnified 30 linear. In other cases the quartz of the grain is clearer, and the contrast less, and in others so slight that it is impossible to be quite sure whether they were originally grains of sand, or only detached parts of the quartz which has crystallized *in situ*. It is, however, almost certain that many such grains must be present, since quartz in general is much more transparent than those grains which are well marked in the manner described. The great difficulty of recognizing clear grains must be borne in mind, since the apparent absence of sand from some specimens of schist may be due to this cause.

Fig. 9.—*Grain of Quartz-sand in the Mica-schist of Arroquhar.*



Along with the grains of quartz just described occur some of what appear to have been felspar, much decomposed before the deposit was altered into schist; and there are also some grains very much as if they had been derived from a felsite. In some respects these various felspathic grains are more distinct than those of quartz, because they are granular and quite unlike the surrounding rock. Possibly this is why they are sometimes seen in specimens of schist in which no grains of quartz can be recognized; but still the evidence is not so reliable as in the case of milk-white quartz, since one cannot but feel that it is always possible, even when it is not probable, that they are portions of altered felspar which crystallized *in situ* when the rock was metamorphosed. In any case, taking all the facts into consideration, the proof of the original presence of true grains of sand in some thoroughly crystalline and typical mica-schists is as perfect as in the case of slates. Leaving doubtful cases out of consideration, about $\frac{1}{5}$ of all my sections of schist afford good evidence of the presence of such grains; and I find that also $\frac{1}{5}$ of my sections of slates show similar grains; so that their absence from $\frac{4}{5}$ of my specimens of schists is no valid objection to their having been originally of as true detrital origin as slates, since these specimens are probably due to the alteration of slates which contained no sand.

The evidence of the original fine-grained material is occasionally tolerably satisfactory, but often equivocal. We must always be on our guard not to mistake a portion of decomposed or altered felspar for the original fine-grained base of a slate, and can place no reliance on observations made with specimens of gneiss. I would base my arguments wholly on what may be seen in true mica-schist, in which there is no good evidence of the former presence of crystalline felspar, either in broken fragments or as crystals formed *in situ*. All the sections examined were prepared by myself, and no polishing material used; so that I am quite sure that none of the appearances is due to any thing of that kind sticking to the objects. The best examples I have seen are from Skateraw and Muchals, on the sea-coast between Aberdeen and Stonehaven. In them I have not been able to find any independent proof of the former presence of felspar, or of any other mineral likely to yield fine-grained pseudomorphs. The patches which I take to be portions of the slightly-altered original rock show no trace of crystalline form, and have no well-defined outline, but, on the contrary, pass gradually into the surrounding schist. They have also a decided general structure parallel to the well-marked stratification of the rock, which would not be at all probable if they were not really portions of material mechanically deposited. They are as fine-grained as any slate, and correspond closely with certain light-coloured slightly altered rocks met with in the mountains of North Wales, not far south of Aber. On the whole, taking every thing into consideration, the facts seem to indicate strongly that the patches are not pseudomorphs, but those portions of an original fine-grained rock which have not recrystallized into large crystals of mica and quartz. This supposition, of course, agrees so well with the evidence derived from the quartz-sand, that perhaps we may adopt it provisionally, even though we might feel bound to admit that, without independent evidence, the facts are insufficient to justify such an important conclusion. A large proportion of my sections of mica-schist furnish more or less distinct evidence of the like kind, which, however, in most cases, may be said rather to agree with the supposition that they were originally fine-grained strata than to really prove it. As a general rule, all that can be confidently asserted is, that the great bulk of the rock is composed of minerals which have so crystallized *in situ* that the original structure has been almost or altogether obliterated.

Original Source of the Material of some Schists.

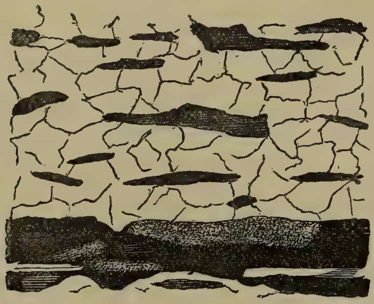
As shown above, there is sufficiently good proof that the schists of the central Highlands of Scotland were originally slates; and it would obviously be interesting to know the nature of the rocks from which their material was derived. There are, however, some serious difficulties to contend with in deciding this question. The number of well-marked quartzose grains is not great; and the felspathic grains are certainly somewhat altered; and it is difficult, if not impossible, to say how much they are changed, and to be sure that some of the grains which look like felsite are not partially decomposed felspar altered into a felsite-looking substance. Moreover, since it is only those quartz grains which have a somewhat unusual structure that can now be recognized with perfect confidence, they necessarily make it appear as if the original rock were of more unusual character than it really was. I have done my best to form a satisfactory conclusion; and allowance must be made for the unavoidable difficulties.

The most striking peculiarity of the grains of quartz is that they often contain many minute hair-like crystals, which possibly are rutile, and also many minute granules and fluid-cavities, sometimes with included crystals of alkaline chlorides. In my collection I have no section of a granite or felsite which shows these characters combined. There are many of the hair-like crystals in the quartz of the granite of Aberdeen; but it is on the whole far more transparent, and shows the milk-white appearance in far less degree, than the quartz-sand of the schists, and also contains comparatively few fluid-cavities or granules. As far as the fluid-cavities are concerned, the quartz of the grains is far more like that of the Cornish granites; but this latter contains few if any of the hair-like crystals, and many of the much stouter crystals of schorl. I have also been able to detect in the grains in the schists a few well-marked enclosures of what looks like a fine-grained felsitic base, as though they had been derived from a quartz felsite; but yet they are not sufficiently numerous to indicate exclusively an extreme type of felsite. On the whole, taking into consideration the character of both the felspathic and quartzose grains, the most satisfactory conclusion appears to be that the material was, to a considerable extent derived from a granite of a type very unlike those of Cornwall, but in some respects analogous to that of Aberdeen, though differing from it in being more like a quartz felsite. Perhaps, then, speaking generally, we may say that it was mainly derived from a felsite of medium character, or partly from a more perfect granite, and partly from a felsite of more extreme type. This conclusion, of course, applies only to the particular district now under consideration. The source of the material, in the case of other districts, could, I think, be ascertained in a similar manner, at all events within certain limits.

Stratification-foliation.

In those schists which have stratification-foliation, the large flat crystals of mica lie in the plane of the beds of different mineral nature; but still the structure differs essentially from true stratification. Sometimes the parallelism is of only a very general character, and horizontal segregation has taken place to a large extent, in the manner explained when describing the specimens of slate from Wicca Pool altered into fine-grained schist. However, as in some of the specimens from Wicca Pool, there has sometimes been little or no horizontal segregation, and the bands of different mineral composition are continuous, like small deposited beds; but frequently some of these are so exclusively quartzose, and others so exclusively micaceous, that I think the original differences due to stratification must have been greatly increased by vertical segregation. Even when this kind of evidence is wanting, the mutual arrangement of the constituent crystals clearly shows that their present outline is due to growth *in situ*. A portion of a specimen from Loch Goyle, magnified 60 linear, shown by fig. 10,

Fig. 10.—*Mica-schist of Loch Goyle, with stratification-foliation.*



will serve to illustrate some of the more important facts. At the bottom we have a layer containing much mica, and in the centre one composed more exclusively of quartz. In this layer lie large and smaller plates of mica, enclosed in a number of interfering crystals of quartz, which have obviously crystallized *in situ* round them and about them. Similarly, when we examine the micaceous layer, we may see that the crystals of mica also mutually interfere and enclose quartz, so that the proof of crystallization *in situ* is equally good.

Cleavage-foliation.

It is, however, in the case of cleavage-foliation that the proof of recrystallization is the most complete; and since the great importance of this structure appears to be often overlooked, it will be well to consider it somewhat in detail.

By far the best district that I have seen for studying this kind of foliation is that lying along the sea-coast between Aberdeen and Stonehaven, especially at Portlethon, Muchals, and Skateraw. At Muchals I obtained specimens which are remarkably instructive, because they show in the same thin section both stratification-foliation and cleavage-foliation. First of all, we may see bands of different mineral character showing stratification as clearly as any slate, but necessarily modified by a variable amount of horizontal and vertical segregation. Roughly parallel to these thin beds lie many laminar crystals of pale green mica, crumpled up and contorted by lateral pressure, like the thin beds in the slate of Liskeard, shown in fig. 4. As in that slate, many planes of discontinuity have been formed by fracture; and along these larger and more colourless crystals of mica have grown, with their faces and cleavage parallel to the walls, just as in some of the slightly altered slates previously described. Passing to another specimen, the mica, thus formed along the planes of cleavage-discontinuity, increases in amount until, in some parts, it altogether preponderates over the contorted laminæ which are roughly parallel to the bedding, and we see a foliation due to large plates of mica lying in a plane corresponding to true slaty cleavage, inclined at a high angle to the stratification. In other specimens the large irregular crystals of both light- and dark-coloured mica lie almost wholly in the plane of cleavage, but yet here and there are a few which have obeyed the influence of the stratification. In a splendid specimen from Portlethon the cleavage-foliation is very perfectly developed, and is not only parallel to the axis planes of the larger contortions, but has all the other characteristic relations of true slaty cleavage. As an illustration of this kind of foliation I subjoin fig. 11, which represents (magnified 30 linear) a part of a thin band of mica-schist, where the foliation and bedding are at right angles to one another. As in the stratification-foliation, shown by fig. 10, the study of the detail shows very clearly that dark- and light-coloured mica and quartz have all crystallized *in situ*; but it is unnecessary to base the argument on the minute detailed arrangement of the crystals, since no one would suppose that plates of mica could be mechanically deposited sticking upright, and still remain almost parallel after the rock had been contorted.

Fig. 11.—*Mica-schist of Portlethon, with cleavage-foliation.*

Though I have never seen this kind of foliation better developed than in the localities named above, I have also met with it in some of the schists near Inverary and in Anglesey. The intermediate kind, in which the stratification-foliation has been bent into small contortions, and only a little mica has crystallized along the planes of discontinuity, is met with more frequently. The differences in the character of the foliation in the different specimens now described appear to have depended on whether or not the rock became completely solid and crystalline before it was compressed, or was compressed before it became solid and crystalline. The intermediate varieties were probably formed when there was a partial metamorphism before compression, and further crystallization afterwards.

Schists not mechanically deposited as such.

I have most carefully examined my various sections of schists, in order to ascertain whether their structure would in any way countenance the supposition that the constituent minerals were originally formed as a loose crystalline deposit from the sea, and not formed *in situ* by the alteration of a more normal deposit. If such had been the case, we might very well expect to find the cavities between the quartz-grains filled up with quartz, since the associated veins clearly show that it has been largely introduced into the rock since deposition. There is, however, often little or no evidence of any such extensive introduction of mica; so that I doubt if we ought to look upon it as at all probable that mica could have been so deposited chemically as to fill in the spaces between them and complete crystals mechanically deposited, and not leave some well-marked evidence of such a double origin. However, on most carefully studying the character and arrangement of the mica in schists, I saw that the crystals, which are often of considerable size, are fitted and dovetailed together in the most complicated but yet most accurate manner, just as if they had crystallized *in situ*. The individual crystals are well defined, because they are highly dichroic; and by using a polarizer alone they show very marked differences in tint, due to their different orientation, and nothing to indicate a second growth. I can scarcely believe that any one would contend that the mica of those schists which possess cleavage-foliation had been deposited mechanically. If such a view could be maintained, it would be in the case of stratification-foliation; but even then the manner in which the crystals interfere with one another is just as it is in schists with cleavage-foliation, or even in granite itself. The crystals of hornblende and other minerals also interfere in the same manner.

Taking, then, all the facts into consideration, there appears to be very complete proof that the principal constituent minerals of the schists, from the districts examined, were not deposited mechanically, but were formed or recrystallized *in situ*. In some cases there is satisfactory evidence to show that previous to the crystallization the rock was analogous to normal slates; and even when there is no such positive evidence, there is nothing against this supposition, but much in its favour. As far as my observations go, they thus most completely bear out the prevalent theory of the true metamorphic origin of schists; but, at the same time, the specimens which I have examined have been too exclusively derived from particular districts to warrant my extending this conclusion to all rocks of similar general character in other localities, or of earlier epoch than those of the central Highlands of Scotland. A much more extended inquiry would be necessary. But I am fully convinced that the true nature of all such rocks could be learned by the further application of the methods now described.

Conclusion.

It will thus be seen that my aim has been to trace the origin of the material of stratified rocks, and afterwards to study the various mechanical and chemical changes to which it has been subjected, and thus to show the connexion between modern mud and our oldest schistose rocks. In some cases there has been a complete cycle, the material having been derived from crystalline rocks, then deposited mechanically, and finally reconverted into crystalline rocks. In thus dealing with such a wide subject, as a whole, I have been led to treat some questions in a manner which may appear rather unusual, but, as I believe, not on that account less correctly. I cannot but feel how much of the detail still remains unknown; and probably when known it will be found necessary to modify some of my general conclusions. We often meet with two or more structures, each clearly enough due to different causes, and many of such an intermediate character that it is extremely difficult to form a just estimate of the relative influence of the various causes which have probably conspired to produce the result. This and other unavoidable difficulties necessarily make such a first attempt somewhat imperfect; yet I trust that what I have said may, at all events, serve in some measure to point out what may be done, and to lead others to investigate the subject more completely. Considering the very wide range of subjects which I have been compelled to examine from a more or less novel point of view, it is satisfactory to find that in most cases the new facts tend only to remove doubts, and seldom, if ever, do more than slightly modify the conclusions arrived at by geologists from the consideration of totally different and independent evidence.

February 25, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Joseph H. Cowham, Esq., Westminster Training College, S.W.; William Alexander Forbes, Esq., B.A., 14 Ashley Place, S.W.; M. H. Gray, Esq., Kuching, Sarawak, Borneo; and Charles Thomas Whitmell, Esq., M.A., B.Sc. (Lond.), F.C.S., 51 Havelock Street, Sheffield, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that a communication had been received from the American Academy of Arts and Sciences, stating that the Academy proprosed to celebrate its 100th Anniversary on May 26, 1880, on which occasion the Academy hoped that one or more Delegates from the Geological Society of London might be present.

The following communications were read:—

1. "On the Geology of Anglesey." By Prof. T. M'Kenny Hughes, M.A., F.G.S.

2. "Notes on the Strata exposed in laying out the Oxford Sewage-Farm at Sandford-on-Thames." By E. S. Cobbold, Esq., F.G.S., Assoc.M.Inst.C.E.

3. "A Review and Description of the various Species of British Upper-Silurian Fenestellidæ." By G. W. Shrubsole, Esq., F.G.S.

The following specimens were exhibited:—

Quartz and quartz ornaments from Japan, and Agates, exhibited by Prof. James Tennant, F.G.S.; and Specimens exhibited by Prof. T. M'Kenny Hughes and G. W. Shrubsole, Esq., in illustration of their papers.

March 10, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

John Ward, Esq., Lenoxvale, Belfast, was elected a Fellow; and Prof. F. von Hochstetter, of Vienna, and Prof. A. Renard, of Brussels, Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The following communication was read:—

1. "On the Geological Relations of the Rocks of the South of Ireland to those of North Devon and other British and Continental Districts." By Professor Edward Hull, M.A., LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland.

March 24, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

H. T. Burls, Esq., Paramaribo, Dutch Guiana; John Allen M'Donald, Esq., M.Inst.C.E., Holly Place, Hampstead, N.W.; and Rev. Thomas Edward Woodhouse, B.A., 183 Amhurst Road, Hackney, N., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

1. "The Newer Pliocene Period in England.—Part I. Comprising the Red and Fluvio-marine Crag and Glacial Formations." By Searles V. Wood, Esq., Jun., F.G.S.

April 14, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Colville Brown, Esq., 5 Hilldrop Road, Tufnell Park, N.; John N. Dufty, Esq., Tuxford, Notts; and George Benjamin Nichols, Esq., C.E., Handsworth, Staffordshire, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that a subscription, which had been started some time since by the Assistant Secretary, had enabled him to purchase four small Microscopes for use, when necessary, at the Evening Meetings of the Society. These were exhibited on the table, and were now presented to the Society in the names of the Subscribers, to whom the thanks of the Society were due.

The following is a list of the Subscribers:—

H. Beuerman, Esq.
Prof. T. G. Bonney, F.R.S.
E. Crane, Esq.
Prof. P. Martin Duncan, F.R.S.
Sir P. de M. Grey-Egerton, Bart., F.R.S.
R. Etheridge, Esq., F.R.S., Pres. G. S.
John Evans, Esq., F.R.S.
William Francis, Esq.
J. Starkie Gardner, Esq.
Henry Hicks, Esq.
W. H. Hudleston, Esq.
Prof. T. M'Kenny Hughes.
J. W. Hulke, Esq.
E. Hull, Esq., F.R.S.
J. Gwyn Jeffreys, Esq., F.R.S.
Prof. J. W. Judd, F.R.S.
J. Murie, Esq.
S. R. Pattison, Esq.
J. A. Phillips, Esq.
Prof. J. Prestwich, F.R.S.
F. G. H. Price, Esq.
Prof. A. C. Ramsay, F.R.S.
Warington W. Smyth, Esq., F.R.S.
H. C. Sorby, Esq., F.R.S.
J. F. Walker, Esq.

The President further announced that, in accordance with an invitation received from the Geological Society of France, Mr. Thomas Davidson, F.R.S., was deputed by the Council to represent the Society at the celebration of the Fiftieth Anniversary of the foundation of the French Society. Mr. Davidson reports that he was received with great distinction; and the Council have received an intimation from M. de Lapparent, President of the Geological Society of France, that the Society had been exceedingly gratified by the sympathy manifested in the delegation of Mr. Davidson.

Mr. Davidson spoke as follows as Delegate from the Geological Society of London to the Geological Society of France, at the celebration of their Fiftieth Anniversary, on the 1st of April, 1880:—

Monsieur le Président et chers Confrères,—C'est pour moi un bien grand honneur et plaisir de me trouver aujourd'hui parmi vous.

Depuis quarante-une années je fais partie de votre société, et représente actuellement un du petit nombre qui reste de ceux qui composaient la Société Géologique de France en 1839. C'est aussi à la France et à mon vénéré maître et ami Constant Prévost que je dois mes premières impressions en géologie et en paléontologie.

Paris est par excellence la capitale qui offre le plus de facilités et de ressources à ceux qui désirent acquérir une éducation scientifique. Ses cours publics et gratuits à la Sorbonne, au Jardin des Plantes, à l'École des Mines, &c. ont puissamment contribué à l'avancement de la science, et ont été le berceau de tant d'hommes qui se sont distingués depuis le commencement de ce siècle. Paris est aussi le grand centre de culture intellectuelle et du progrès, et de toutes parts on y puise des idées et des faits qui tendent à amplifier et à perfectionner les connaissances humaines.

Messieurs, je suis venu expressément de Londres, à la demande du Président, du Conseil, et des 1415 personnes qui composent la Société Géologique de Londres, afin de les représenter à votre cinquantième anniversaire, et pour vous témoigner la profonde sympathie et l'esprit de fraternité le plus sincère qu'éprouve la Société Géologique de Londres envers vous. Ils me prient de vous assurer qu'ils apprécient au plus haut dégré la part si importante que la Société Géologique de France a prise au mouvement scientifique des cinquante dernières années, et qui a jeté une si vive lumière sur tout ce qui concerne les sciences géologiques et paléontologiques.

Il me semble opportun en ce moment de vous rappeler que tout récemment la société anglaise a adjugé à un de vos membres, notre savant confrère M. A. Daubrée, la médaille de Wollaston pour ses admirables travaux. Oui, Messieurs, la science n'a qu'une seule patrie, le monde entier; et nous n'avons tous qu'un seul but, l'avancement de la science et le désir d'approcher le plus près possible de la vérité. Nos discussions, nos divergences d'opinions sont nécessaires et logiques, car d'une question bien débattue la vérité surgit le plus souvent.

La Société Géologique de Londres, depuis sa fondation en 1807, a comme vous prospéré et doté le monde de nombreux travaux, et même quelques-uns de ses anciens membres, tel que le Dr. Bigsby, qui fit partie de la Société Géologique en 1823, continuent actuellement à publier des travaux importants. La Société Géologique de Londres fait des vœux les plus ardents pour que vous continuiez à prospérer, car quoique nous ayons obtenu de bien beaux résultats, nous savons tous qu'il reste infiniment plus à découvrir, à généraliser, et à perfectionner avant que nous ayons résolu d'une manière satisfaisante les nombreux problèmes qui font partie du domaine géologique.

La paléontologie, fondée par l'immortel Cuvier, et formant partie intégrante de la géologie sédimentaire, demande une étude continue et sérieuse, car le géologue y a constamment recours, et il est de toute nécessité que l'identification des espèces qui caractérisent les terrains et les horizons géologiques soit précise. Je ne puis suffisamment supplier les paléontologistes de tous les pays qui décrivent des espèces nouvelles d'en donner en même temps des figures. Le manque de figures cause souvent le plus grand embarras, et jette une incertitude et même une confusion déplorable dans la synonymie et la nomenclature. Les admirables travaux paléontologiques exécutés en France sont appréciés par le monde entier, et je me plais en cette occasion de rendre hommage à Alcide d'Orbigny, Deshayes, De Verneuil, Barrande et tant d'autres qui ont rendu de si éminents services à la paléontologie française.

Messieurs, quoique je sois délégué tout spécialement par la Société Géologique afin de la représenter en cette mémorable occasion, toutes nos principales sociétés géologiques, zoologiques, et d'histoire naturelle ont bien voulu me charger de les représenter, et de vous témoigner le profond intérêt qu'elles éprouvent pour la prospérité de votre Société, ainsi que pour le succès de vos travaux. Ils vous félicitent donc bien sincèrement d'avoir atteint un demi siècle d'existence, et vous envoient leur meilleurs souhaits pour le temps à venir.

Messieurs, l'esprit le plus cordial de fraternité existe en Angleterre envers la nation et le peuple français ; nos efforts communs doivent être dirigés à nouer étroitement ces sentiments, et à n'avoir d'autre rivalité que celle qui concerne l'avancement de la civilisation et des connaissances humaines.

Je suis chargé par les Présidents et Conseils des Sociétés suivantes de vous féliciter en leur nom :—

La Société Royale de Londres. (Notre Académie des Sciences.) Président M. W. Spottiswoode, F.R.S. Fondée en 1660. 540 Membres.

La Société Linnéenne de Londres. Président M. le Prof. G. J. Allman, F.R.S. Fondée en 1788. 600 Membres.

La Société Zoologique de Londres. Président M. W. H. Flower, F.R.S. Fondée en 1826. 3300 Membres.

La Société Paléontoloique de Londres. Président M. le Prof. R. Owen, C. B., F.R.S. Fondée en 1847. 500 Membres.

L'Association Géologique de Londres. Président M. le Prof. T. Rupert Jones, F.R.S. Fondée en 1858. 400 Membres.

La Société Royale d'Édimbourg. Président Lord Moncrieff, Vice-Président Sir Wyville Thomson, F.R.S. Fondée en 1783. 400 Membres.

La Société Géologique d'Édimbourg. Président M. D. Milne-Home. Fondée en 1834. 230 Membres.

La Société Géologique de Glasgow. Président Sir William Thomson, F.R.S. Fondée en 1858. 300 Membres.

L'Académie Royale d'Irlande. Président Sir Robert Kane. Fondée sous le Règne de George III. 450 Membres.

La Société Royale Géologique d'Irlande. Président M. G. W. Kinahan, M.R.I.A. Fondée en 1833. 180 Membres.

M. le Prof. Ramsay, Directeur Général du Survey Géologique de la Grande Brétagne et du Muséum de Géologie Pratique (École des Mines) me charge de le représenter auprès de vous, et de vous assurer de l'intérêt profond et sincère qu'il prend à la prospérité de la Sociéte Géologique de France.

Il ne reste plus qu'une partie du nord de l'Angleterre, de l'Écosse, et de l'Irlande à compléter (comme vous pouvez vous en assurer par les cartes qu'il me prie de vous présenter) pour avoir terminé une des cartes géologiques les plus détaillées et les plus importantes qui aient été publiées.

Messeiurs,les sciences géologiques et paléontologiques sont éminemment cultivées en Angleterre, ainsi que dans nos Colonies, et la plus part des villes anglaises ont leur sociétés géologiques ou de l'histoire naturelle avec des musées souvent du plus grand intérêt. Plus de 16,000 espèces anglaises ont été cataloguées et classés par terrains et par horizons géologiques par M. Etheridge, Président de la Société Géologique de Londres. Cet ouvrage important est en ce moment sous presse, et paraîtra sous les auspices de l'Université d'Oxford.

La Société Paléontologique de Londres est de même très prospère. Elle a depuis 1847 publié 35 volumes contenant environ dix mille pages et 1380 planches, et qui ont coûté à la Société près de 25,000 livres sterling. Les immenses avantages à la science présentés par une pareille société ne peuvent être exagérés, tous les fonds obtenus par une souscription annuelle très modérée étant employée à solder les frais d'impression et de la confection des planches.

La Suisse en 1874 a créé une Société Paléontologique sur le modèle de celle de Londres, qui a évidemment prospéré, car chaque année son volume a grossi. Je suis persuadé, et nombre de mes compatriotes partagent la même idée, que si l'on établissait à Paris une semblable société, les resultats seraient des plus précieux et faciliteraient la publication de nombreuses monographies que les sociétés géologiques ou autres ne peuvent entreprendre.

L'Association Géologique de Londres a aussi rendu de très grands services à la science. Fondée il y a vingt-une années par un nombre de jeunes gens qui désiraient apprendre la géologie économiquement par l'aide mutuel, et par la discussion entre eux des questions géologiques dans les localités mêmes, et avec de véritables coupes sous les yeux, cette société a formé d'excellents géologues, et bon nombre de leur travaux ferait honneur à des géologues de plus de prétention.

La géologie des nos jours n'est pas celle de 1830. On n'est plus content de diviser les terrains en quelques grandes formations ou systèmes. On a établi et on cherche à établir de nombreuses sous-divisions ou horizons géologiques caractérisés par la présence de certaines espèces d'ammonites ou autres formes spéciales. Ce système a obligé les géologues à'étudier en grand détail chaque couche avec une scrupuleuse attention; seulement il faut se garder de vouloir arbitrairement empêcher telle ou telle espéce de franchir les limites de son soi-disant horizon. En Angleterre, comme en France, on attache la plus grande importance à ces sous-divisions, et je saisis cette occasion de remercier au nom de mes compatriotes MM. Hébert, Barrois et autres d'avoir bien voulu franchir le détroit afin de comparer leurs horizons avec ceux de l'Angleterre. Leurs travaux et leurs vues ont été très appréciés et adoptés, et nous serions bien reconnaissant que ces études comparatives soient continues, car tout ce qui concerne la géologie de la France a pour nous le plus vif intérêt, et il doit en être de même relativement à l'Angleterre pour les géologues français. Cet échange d'observations et d'idées tend éminemment au progrès de la science.

Messieurs, je n'ai pas le désir d'occuper plus de votre temps. Ma tâche, bien agréable, étant accomplie, j'ai l'honneur au nom de mes compatriotes scientifiques de vous féliciter en cette mémorable occasion.

The following communications were read:—

1. "On a new Theriodont Reptile (*Cliorhizodon orenburgensis*, Twelvtr.) from the Upper Permian Sandstone of Kargalinsk, near Orenburg, in South-eastern Russia." By W. H. Twelvetrees, Esq., F.L.S., F.G.S.

2. "The Classification of the Tertiary Period by means of the Mammalia." By Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S., Professor of Geology in Owens College.

A specimen was exhibited in illustration of Mr. Twelvetrees's paper on *Cliorhizodon orenburgensis*.

April 28, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Rev. James Oliver Bevan, M.A., Russell House, Walmley, Birmingham; Arnold Hague, Esq., Washington, U.S.; Augustus Constable Maybury, Esq., M.R.C.S., 23 Charlotte Street, Bedford Square, W.C.; Henry Peter Meaden, Esq., Hallgarth Street, Durham; William Peregrine Propert, Esq., M.A., LL.D., The Cross House, St. Davids, Pembrokeshire, and 1 Hare Court Temple, E.C.; and Francis Randell, Esq., Corsham, Wilts, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "Description of Parts of the Skeleton of an Anomodont Reptile (*Platypodosaurus robustus*, Ow.) from the Trias of Graaff Reinet, South Africa." By Prof. Owen, C.B., F.R.S., F.G.S.

2. "Note on the Occurrence of a new Species of *Iguanodon* in the Kimmeridge Clay at Cumnor Hurst, three miles west of Oxford." By Prof. J. Prestwich, M.A., F.R.S., F.G.S.

3. "On *Iguanodon Prestwichii*, a new Species from the Kimmeridge Clay." By J. W. Hulke, Esq., F.R.S., F.G.S.

Specimens were exhibited by Prof. Prestwich in illustration of his and Mr. Hulke's papers.

May 12, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Rev. Samuel Gasking, 10 Cheetham Hill Road, Stalybridge; Thomas John George, Esq., Keyston, near Thrapston; and Cuthbert Chapman Gibbes, Esq., M.D., Surbiton Hill, Kingston-on-Thames, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Structure and Affinities of the Genus *Protospongia*, Salter." By W. J. Sollas, Esq., M.A., F.G.S.

2. "Notes on *Psephophorus polygonus*, von Meyer, a new Type of Chelonian Reptile allied to the Leathery Turtles." By Prof. H. G. Seeley, F.R.S., F.G.S.

3. "On the Occurrence of the Glutton (*Gulo luscus*, Linn.) in the Forest-bed of Norfolk." By E. T. Newton, Esq., F.G.S.

[Abstract *.]

Remains of the Glutton have hitherto been obtained only from cave-deposits. The author has lately received from Mr. R. Fitch, of Norwich, a portion of the lower jaw of this animal obtained from the Forest-bed of Mundesley, Norfolk. The specimen consists of about 2 inches of the left ramus, bearing the first true molar and the hinder half of the fourth premolar in place. The jaw is smaller

* This paper has been withdrawn by the author.

than in average specimens of the recent Glutton, but presents all the characters of the species as described in detail by the author.

Discussion.

The President remarked on the interest of the particular specimen, the exact horizon of the occurrence of which had been so accurately fixed.

Mr. Gunn stated that he had frequently found gnawed bones of various mammals in the forest-bed, and he laid such a gnawed specimen of a deer's bone before the Society. He also remarked upon the complication of the series of strata known as the "Forest-bed series."

4. "A Review of the Family Diastoporidæ, for the purpose of Classification." By George Robert Vine, Esq. Communicated by Prof. Duncan, F.R.S., F.G.S.

5. "On Annelid Jaws from the Wenlock and Ludlow Formations of the West of England." By G. J. Hinde, Esq., F.G.S.

The following specimens were exhibited:—

Gold in quartz from Nova Scotia, and "Cats-eyes" from Ceylon and South Africa, exhibited by Prof. J. Tennant, F.G.S.

A cast of the jaw of *Gulo luscus*, exhibited by Mr. Newton, and specimens of Annelid jaws, exhibited by Mr. Hinde, in illustration of their papers.

A new form of Microscope, adapted for petrological research, was exhibited by Mr. Watson, of Pall Mall.

May 26, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Prof. Frederick Guthrie, F.R.S., Science Schools, South Kensington, S.W.; Rudolf Hænsler, Esq., Ph.D., Western College, Harrogate; James Hulme, Esq., Bury Hall, Wolverley, Worcestershire; William Jolly, Esq., F.R.S.E., Inverness; Charles Myhill, Esq., Curzon School House, May Fair, W.; and Alfred George Savile, Esq., B.A., Grosvenor School, Nottingham, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "The Pre-Carboniferous Rocks of Charnwood Forest."—Part III. Conclusion. By the Rev. E. Hill, M.A., F.G.S., and Prof. T. G. Bonney, M.A., F.R.S., F.G.S.

2. "On the Geological Age of Central and West Cornwall." By J. H. Collins, Esq., F.G.S.

3. "On a Second Precambrian Group in the Malvern Hills." By C. Callaway, Esq., D.Sc., F.G.S.

Microscopic sections and rock-specimens were exhibited by Prof. Bonney and Dr. Callaway, in illustration of their papers.

A microscopic section of Italian Eocene "Diaspro," containing an abundance of Radiolaria, was exhibited by A. W. Waters, Esq., F.G.S.

June 9, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

John Burn Anstis Du Sautoy, Esq., C.E., 13 Blenheim Road, Bedford Park, Chiswick, W., and Rev. John Cowley Fowler, B.A., North Stainley Vicarage, Ripon, were elected Fellows; Prof. G. Dewalque, Liége, a Foreign Member, and Prof. Leo Lesquereux, Columbus, U.S., a Foreign Correspondent 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:—E. G. Dyke, Esq., H. H. Gunn, Esq., Jonathan Harrison, Esq., J. T. Johnson, Esq., W. J. Lancaster, Esq., and L. T. Lewis, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Occurrence of Marine Shells of existing Species at different Heights above the present Level of the Sea." By J. Gwyn Jeffreys, LL.D., F.R.S., Treas. G.S.

2. "On the Pre-Devonian Rocks of Bohemia." By J. E. Marr, Esq., B.A., F.G.S.

3. "On the Pre-Cambrian Rocks of the North-western and Central Highlands of Scotland." By Henry Hicks, Esq., M.D., F.G.S.

[Abstract*.]

The author, after examination, considers the rocks of the following districts to be wholly or in part Pre-Cambrian:—

(1) *Glen Finnan and Loch Shiel to Caledonian Canal.*—In the former district the rocks are gneiss, generally massive, with horn-

* This paper has been withdrawn by the author.

blende schists, as at Ben Fin to the north. In Glen Finnilee is a series which the author regards as newer, and probably Pebidian. At Fassfern are quartz rocks which the author identifies with those beneath the limestone in Glen Laggan, near Loch Maree, and probably of Silurian age. At Bannavie is a granite which the author considers to be Pre-Cambrian.

(2) *Fort William and Glen Nevis.*—In this district chloritic schists and gneiss occur, which the author regards as Pebidian. These are overlain towards the south by Silurian rocks.

(3) *Ballachulish, Glen Coe, and Black Mount.*—Chloritic schists and quartzites occur here, followed along Loch Leven unconformably by Silurian rocks. On the east of the Ardsheal peninsula there is granite which the author believes to be Pre-Cambrian. Going eastward from Ballachulish are black slates, probably of Silurian age. In Glencoe are granite-banded felsite, gneiss, and breccias, resembling as a whole the rocks of the Welsh Arvonian group. Between the Black Mount and Loch Sullich are traces of a great Pre-Cambrian axis, bringing up the gneissic series; this is traceable also towards Glen Spean and Loch Laggan to the N.E. Silurian quartzites are also found along broken lines, resting on the gneiss rocks.

(4) *Tyndrum to Callander.*—South and east of the former are gneisses and silvery mica-schists. Crystalline limestones and serpentines are associated near Loch Tay, resembling those in the Pebidian series of North Wales.

The author states that the Silurian (and Cambrian) rocks flank the Pre-Cambrian in lines from N.E. to S.W. Thus here, as elsewhere, subsequent denudation has removed enormous masses of the more recent rocks, only here and there leaving patches of these in folds along depressions in the old Pre-Cambrian floor.

Discussion.

Professor Judd said that the time was too short, and there was a difficulty in finding a common ground for discussion. Dr. Hicks seemed to think that the age of rocks could be fixed by their mineral characters. As to the age of these altered rocks, he thought most geologists held their views in suspense; he, however, thought Dr. Hicks's section offered as great difficulties as any other. Where, for example, were the fossils, if these Silurian beds were not altered, as asserted by Dr. Hicks? He thought the Callander limestones much altered.

Prof. Hughes thought that the specimens exhibited by Dr. Hicks proved that he had at any rate one group of gneissic rocks, and another group of rocks hardly at all altered; and if the unaltered rocks rested on the metamorphic series in the manner described by Dr. Hicks, he must accept Dr. Hicks's reading of the district as regards those two divisions. In reply to Prof. Judd, he maintained that Dr. Hicks's section was quite clear and natural, whether its general accuracy would be confirmed by subsequent observers or not.

Mr. Hudleston said the question was really one of evidence, and, till the section had been examined by several persons, it was difficult to come to a conclusion. In Prof. Harkness's section the limestones were in anticlinals, in Dr. Hicks's they were synclinals. How was it that these Pre-Cambrians had a N.E. strike? From their mineralogical character the rocks of the moor of Rannoch could not in fairness be correlated with the Pebidian.

The President said that the subject was a difficult one to understand clearly. Dr. Hicks, no doubt, had much experience in these older rocks. The Scotch surveyors, with most careful work, had not yet been able to come to a definite conclusion on many points, and the country had not been all surveyed and mapped.

Dr. Hicks said that the Callander rocks, said to be altered by Prof. Judd, were not altered. Mr. Hudleston had forgotten that he had already pointed out that the Pre-Cambrian groups had different strikes. The limestones belonging to the unaltered series were easily distinguishable from those belonging to the metamorphic rocks, though hitherto they had been confounded with one another. The unaltered rocks occurred in broken synclinal folds in each of the areas examined, and very frequently contained fragments from the immediately underlying metamorphic rocks.

The following specimens were exhibited:—

A specimen of *Argonauta*, exhibited by E. Charlesworth, Esq., F.G.S.

Rocks and fossils exhibited by Dr. Hicks and Mr. Marr in illustration of their papers.

June 23, 1880.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Edwin Muir, Esq., M.Inst.C.E., 10 Wellington Street, Higher Broughton, Manchester; Benjamin Sykes, Esq., C.E., Winckley Square, Preston; and John Thorburn, Esq., Ditton, near Widnes, 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:—E. G. Dyke, Esq., H. H. Gunn, Esq., Jonathan Harrison, Esq., J. T. Johnson, Esq., W. J. Lancaster, Esq., and L. T. Lewis, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Skull of an *Ichthyosaurus* from the Lias of Whitby, apparently indicating a new Species (*I. zetlandicus*, Seeley), preserved in the Woodwardian Museum of the University of Cambridge." By Prof. H. G. Seeley, F.R.S., F.G.S.

2. "Note on the Cranial Characters of a large Teleosaur from the Whitby Lias, preserved in the Woodwardian Museum of the University of Cambridge." By Prof. H. G. Seeley, F.R.S., F.G.S.

3. "On the Discovery of the place where Palæolithic Implements were made at Crayford." By F. C. J. Spurrell, Esq., F.G.S.

4. "The Geology of Central Wales." By Walter Keeping, Esq., M.A., F.G.S. With an Appendix by C. Lapworth, Esq., F.G.S., on a new Species of *Cladophora*.

5. "On new Erian (Devonian) Plants." By J. W. Dawson, LL.D., F.R.S., F.G.S.

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.

7. "Färöe Islands. Notes upon the Coal found at Süderöe." By Arthur H. Stokes, Esq., F.G.S.

8. "On some new Cretaceous *Comatulæ*." By P. Herbert Carpenter, Esq., M.A. Communicated by Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.

9. "On the Old Red Sandstone of the North of Ireland." By F. Nolan, Esq., M.R.I.A. Communicated by Prof. Hull, LL.D., F.R.S., F.G.S.

10. "A Review of the Family Vincularidæ, Recent and Fossil, for the purpose of Classification." By G. R. Vine, Esq. Communicated by Prof. P. M. Duncan, M.B., F.R.S., F.G.S.

11. "On the Zones of Marine Fossils in the Calciferous Sandstone Series of Fife." By James W. Kirkby, Esq. Communicated by Prof. T. Rupert Jones, F.R.S., F.G.S.

12. "The Glaciation of the Orkney Islands." By B. N. Peach, Esq., F.G.S., and John Horne, Esq., F.G.S.

The following specimens were exhibited :—

Specimen of brain-case of *Teleosaurus eucephalus* from the Lias of Whitby, exhibited by Prof. T. M'K. Hughes, M.A., F.G.S.

A subangular boulder from the Cambridge Greensand, showing ice-scratches, and a stone hatchet from Horningsea near Cambridge, exhibited by W. Keeping, Esq., M.A., F.G.S.

Specimens were also exhibited by Messrs. Buckman, Spurrell, Keeping, and Horne, in illustration of their papers.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

Session 1879–80.

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. 385–399. 1879.

——. Nos. 400–424. 1880.

G. F. Rodwell. Vesuvius, 124.

Adelaide. Philosophical Society. Transactions and Proceedings for 1877–78. 1878.

G. Scoular. On the Origin of Mineral Veins, with special reference to the Barossa District, 75.—W. T. Bednall. Australian Trigonias and their distribution, 77.—J. E. Tenison-Woods. On some fossil Corals from Aldinga, 104.—R. Tate. Notes on the Correlation of the Coral-bearing Strata of South Australia, with a list of fossil Corals occurring in the Colony, 120.

Albany. New-York State Library. 58th to 61st Annual Reports of the Trustees (1875–78). 1876–79.

——. New-York State Museum of Natural History, 27th to 31st Annual Reports of the Regents of the University of the State of New York (1874–78). 1875–79.

American Journal of Science and Arts. Ser. 3. Vol. xviii. Nos. 103–108. 1879.

J. L. Campbell. Silurian Formation in Central Virginia, 16.—J. Le Conte. Extinct Volcanoes about Lake Mono, and their relation to the Glacial Drift, 35.—G. J. Brush and E. S. Dana. Mineral Locality in Fairfield County, Conn., 45.—J. M. Stillman. Bernardinite, a new Mineral Resin, 57.—O. C. Marsh. Notice of a New Jurassic Mammal, 60.—J. D. Dana. On the Hudson-River Age of the Taconic Schists, 61.—W. Upham. Terminal Moraines of the North-American Ice Sheet, 81.—E. W. Hilgard. The Lœss of the Mississippi Valley and the Æolian Hypothesis, 106.—J. L. Campbell. Geology of Virginia: Continuation of Section across the Appalachian Chain, 119.—J. J. Stevenson. Notes on the Laramie Group of Southern Colorado and Northern New Mexico, east from the Spanish Ranges, 129.—J. D. Dana. On some Points in Lithology, 134.—E. B. Andrews. Discovery of a new Group of Carboniferous Rocks in South-eastern Ohio, 137.—E. Orton. Note on the Lower Waverley Strata of Ohio, 138.—K. Möbius. Principal J. W. Dawson's Criticism of my Memoir on the Structure of *Eozoon canadense* compared with that of Foraminifera, 177.—C. U. Shepard. Estherville, Emmet County, Iowa, Meteorite of May 10th, 1879, 186.—W. Upham. Terminal Moraines of the North-American Ice Sheet, 197.—O. C. Marsh. Additional Remains of Jurassic Mammals, 215.—T. N. Dale, jun. The Fault at Rondout, 293.—S. L. Penfield. Chemical Composition of Amblygonite, 295.—W. J. M'Gee. Superposition of Glacial Drift upon Residuary Clays, 301.—O. C. Marsh. History and Methods of Palæontological Discovery, 323.—C. A. Ashburner. The Kane Geyser Well, 394.—O. C. Marsh. New Jurassic Mammals, 396.—G. C. Broadhead. Origin of the Lœss, 427.—J. L. Campbell. Geology of Virginia, 435.—J. J. Stevenson. Geology of Galistes Creek, New Mexico, 471.—A. W. Vogdes. Geology of Catoosa Co., Georgia, 475.—O. C. Marsh. New Jurassic Reptiles, 501.

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J. D. Dana. G. K. Gilbert's Report on the Geology of the Henry Mountains, 17.—R. P. Whitfield. New Forms of Fossil Crustaceans from the Upper Devonian Rocks of Ohio, 33.—W. B. Dwight. Explorations in the Wappinger Valley Limestone of Dutchess County, N.Y.; Calciferous as well as Trenton Fossils in the Wappinger Limestone at Rochdale, and a Trenton Locality at Newburgh, N.Y., 50.—O. C. Marsh. New Characters of Mosasauroid Reptiles, 83.—W. O. Crosby. Pinite in Eastern Massachusetts; its Origin and Geological Relations, 116.—S. F. Peckham and C. W. Hall. Lintonite and other forms of Thomsonite, 122.—W. J. Comstock. Analyses of some American Tantalates, 131.—O. C. Marsh. The Limbs of *Sauranodon*, 169.—J. Le Conte. The Old River-beds of California, 176.—J. D. Dana. Note on the Age of the Green Mountains, 191.—W. J. Comstock. The Chemical Composition of the Uraninite from Branchville, Conn., 220.—S. W. Ford. Western Limits of the Taconic System, 225.—O. C. Marsh. Principal Characters of American Jurassic Dinosaurs, 253.—T. Sterry Hunt. History of some Pre-Cambrian Rocks in America and Europe, 268.—C. G. Rockwood, jun. Notices of Recent American Earthquakes, 295.—S. L. Penfield. Chemical Composition of Childrenite, 315.—G. J. Brush and E. S. Dana. Note on the Relation between Childrenite and Eosphorite, 316.—G. K. Gilbert. Outlet of Lake Bonneville, 341.—T. Sterry Hunt. Chemical and Geological Relations of the Atmosphere, 349.—A. Geikie. Archæan Rocks of Wahsatch Mts., 363.—S. L. Penfield. Apatites containing Manganese, 367.—W. E. Hidden. Cleberne County Meteorite, 370.—T. Sterry Hunt. Recent Formation of Quartz and Silicification in California, 371.—C. U. Shepard. Ivanpah, California, Meteoric Iron, 381.—J. Lawrence Smith. Daubrée's 'Experimental Geology,' 386.—O. D. Allen and W. J. Comstock. Bastnäsite and Tysonite from Colorado, 390.—O. C. Marsh. The Sternum in Dinosaurian Reptiles, 395.—A. Guyot. Physical Structure and Hypsometry of the Catskill Mountain Region, 429.—W. B. Dwight. Recent Explorations of the Wappinger Valley Limestone of Dutchess County, N.Y., 451.—J. L. Smith. Emmet County Meteorite, that fell near Estherville, Emmet County, Iowa, 459.—R. P. Whitfield. Occurrence of true *Lingula* in the Trenton Limestones, 472.

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T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca: No. XII. Some Carboniferous Species belonging to the Genus *Carbonia*, Jones, 28.—R. Owen. On the Occurrence in North America of rare Extinct Vertebrates found fragmentarily in England, No. 2., 53.—K. A. Zittel. Studies on Fossil Sponges: V. Calcispongiæ, 61, 120.—P. M. Duncan. On some Spheroidal Lithistid Spongida from the Upper Silurian Formation of New Brunswick, 84.—H. J. Carter. On the Mode of Growth of *Stromatopora*, including the Commensalism of *Caunopora*, 101. —O. C. Marsh. Notice of a new Jurassic Mammal, 167.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca: No. XIII. *Entomis serratostriata* and others of the so-called "Cypridinen" of the Devonian Schists of Germany, 182.—H. A. Nicholson and R. Etheridge, jun. Descriptions of Palæozoic Corals from Northern Queensland, with Observations on the Genus *Stenopora*, 216, 265.—H. J. Carter. On the Structure of *Stromatopora*, 253.—J. F. Blake. On the Homologies of the Cephalopoda, 303.—C. Lapworth. On the Geological Distribution of the Rhabdophora, 333, 423.—G. Nevill. Description of a new Species of *Acme* and Varieties from the Conglomerate Beds of Menton, 341.—H. J. Carter. Note on the so-called "Farringdon (Coral-Rag) Sponges" (Calcispongiæ, Zittel), 431.

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C. Lapworth. On the Geological Distribution of the Rhabdophora, 45, 273, 358.—C. Lapworth. On new British Graptolites, 149.—R. Owen. On the Occurrence in North America of rare Extinct Vertebrates found fragmentarily in England, No. 3, 177.—T. Stock. On a Spine (*Lophacanthus Taylori*, mihi, nov. gen. et spec.) from the Coal-measures of Northumberland, 217.—E. D. Cope. The Cave-Bear of California, 260.—J. W. Davis. On the Teleostean Affinities of the Genus *Pleuracanthus*, 349.—A. S. Packard. Fossil Crawfish from the Tertiaries of Wyoming, 435.—R. Etheridge, jun. Notes on the Gasteropoda contained in the Gilbertson Collection, British Museum, and figured in Phillips's 'Geology of Yorkshire,' 473.

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R. Lanciani. The Eruption of Mount Etna, 825.

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A. R. Lockhart. Volcanic Eruption in the Island of Dominica, 219.

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C. J. Kell. On a Displacement or Wash-out of the Barnsley Bed of Coal, at Thrybergh Hall Colliery, 17.—R. Miller. On the South Yorkshire and Midland Coal-fields, with reference to the Barnsley Bed in the Barnsley and Nottinghamshire Districts, 44.

Bedford. Bedfordshire Natural-History Society and Field Club. Abstract of Proceedings and Transactions for the year 1875–76. 1877. *Presented by W. Whitaker, Esq., F.G.S.*

J. Wyatt. On the Geology of Sandy, 42.—W. B. Graham. On the Geology of Sharnbrook, 45.—C. E. Prior. Cornish Notes—Botanical and Geological, 62.—J. Wyatt. On Land and Freshwater Shells found in Bedford Gravels, 76.—W. Hillhouse. The Surface Geology and Physical Geography of Bedfordshire, with especial reference to a Botanical division of the County, 83.

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W. Gault. Observations on the Geology of the Black Mountain, with special reference to the Cretaceous Rocks, 251.—W. Swanston. On the Silurian Rocks of the County Down, Appendix IV., 107.—C. Lapworth. On the Graptolites of County Down, Appendix IV., 125.

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G. Berendt. Gletschertheorie oder Drifttheorie in Norddeutschland? 1.—H. Credner. Ueber Gletscherschliffe auf Porphyrkuppen bei Leipzig und über geritzte einheimische Geschiebe, 21.—H. Eck. Bemerkungen zu den Mittheilungen des Herrn G. Pohlig "Ueber *Aspidura*, ein mesozoisches Ophiuridengenus" und über die Lagerstätte der Ophiuren im Muschelkalk, 35.—E. Kayser. Zur Frage nach dem Alter der hercynischen Fauna, 54.—A. Helland. Ueber die Glacial-Bildungen der nordeuropäischen Ebene, 63.—C. Rammelsberg. Ueber die Zusammensetzung des Kjerulfins, 107.—E. Weiss. Bemerkungen zur Fructification von *Nœggerathia*, 111.—A. Penck. Die Geschiebeformation Norddeutschlands, 117.—C. Struckmann. Ueber den Serpulit (Purbeckkalk) von Völksen am Deister, über die Beziehungen der Purbeckschichten zum oberen Jura und zum Wealden und über die oberen Grenzen der Juraformation, 227.—Max Bauer. Die Krystallform des Cyanits, 244.—H. Eck. Ueber einige Triasversteinerungen, 254.—R. Richter. Aus dem thüringischen Diluvium, 282.—E. Kayser. Ueber einige neue Versteinerungen aus dem Kalk der Eifel, 301.—D. Brauns. Die Bryozoen des mittleren Jura der Gegend von Metz, 308.—F. Nötling. Ueber das Vorkommen von Riesenkesseln im Muschelkalk, 339.—Rothpletz. Ueber mechanische Gesteinsumwandlungen bei Hainichen in Sachsen, 355.—J. Roth. Der Ausbruch des Aetna am 26. Mai 1879, 398.—O. Meyer. Einiges über die mineralogische Natur des Dolomits, 445.—Grumbrecht. Bemerkungen über Einschnitte der Eisenbahn zwischen Goslar und Vienenburg in der oberen Kreide, 453.—A. von Lasaulx. Die Salinellen von Paterno am Etna und ihre neueste Eruption, 457.—K. Martin. Phosphoritische Kalke von der westindischen Insel Bonaire, 473.—T. Dahll. Ueber Norwegium, ein neues Schwermetall, 480.—O. Lang. Ein Beitrag zur Kenntniss norwegischer Gabbro's, 484.—A. Penck. Ueber Palagonit- und Basalttuffe, 504.—Trautschold. Ueber Eluvium, 578.—C. Schlüter. Neue und weniger gekannte Kreide- und Tertiär-Krebse des nordlichen Deutschlands, 586.—F. Römer. Notiz über ein Vorkommen von oberdevonischen Goniatiten-Kalk in Devonshire, 659.—H. Wöckener. Ueber das Vorkommen von Spongien im Hilssandstein, 663.—C. Schlüter. *Coelotrichium Decheni*, ein Foraminifere aus dem Mitteldevon, 668.—C. Rammelsberg. Ueber die chemishe Zusammensetzung der Glimmer, 676.—G. Berendt. Cyprinenthon von Lenzen und Tolkemit in der Gegend von Elbing, 692.—L. Meyn. Das Porphorit-Lager von Curaçao, 697.—A. Halfar. Ueber die Vergletscherung der Faröer sowie der Shetland- und Orkney Inseln, 716.—H. Loretz. Untersuchungen über Kalk und Dolomit, 756.—O. Lang. Ueber einen Pendel-Seismograph, 775.

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C. Rammelsberg. Ueber die Fortschritte in der Kenntniss der chemischen Natur der Meteoriten, 372.—J. G. Galle und A. von Lasaulx. Bericht über dem Meteorsteinfall bei Gnadenfrei am 17. Mai 1879, 750.—Rammelsberg. Ueber die chemische Zusammensetzung der Glimmer, 833.

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Casts of three-toed foot-prints from the Triassic conglomerate of South Wales. *Presented by W. J. Sollas, Esq., F.G.S.*

Geyserites from Colorado. *Presented by Dr. F. V. Hayden, F.M.G.S.*

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