THE

QUARTERLY JOURNAL

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.*

VOLUME THE TWENTY-EIGHTH.

1872.

PART THE FIRST.
PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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ERRATA ET CORRIGENDA.

Page 11, footnote, line 2 from bottom, *for* "was" *read* "were."
,, 114, line 9 from bottom, *before* "fig. 34," *insert* "Pl. 1."
,, 114, lines 8 and 7 from bottom, *transpose* "Berthelotiana" *and* "hirsuta."
,, 118, after line 26, *insert* "CALCARINA tetraedra (*Gümb.*)"
,, 118, line 27, *for* "Rottaline" *read* "Rotaline."
,, 123, *insert* * in 13th column opposite "CALCARINA."
,, 125, line 22, *insert* "fossile" *before* "Foraminiferen."
,, 127, line 8 from bottom, *for* "cristellaroides" *read* "cristellarioides."
,, 180, line 9 from bottom, *for* "Tablse" *read* "Tables."
,, 245, line 24, *before* "some" *insert* "in."
,, 272, right hand of lower figure for "*c*" read "*d*."
,, 318, line 11, *before* "England" *insert* "in."
,, 356, line 13, *for* "linea" *read* "linear," and *for* "Træniopteroid" *read* "Tæniopteroid."
,, 382, line 29, *for* "a" *read* "area."
,, 396, line 10 from bottom, *for* "chlorite" *read* "glauconite."
,, 439, line 21, *for* "Scotldan" *read* "Scotland."
,, 496, line 23, *for* "Northern" *read* "Northam."

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PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

November 8, 1871.

Henry Hicks, Esq., M.R.C.S., of Heriot House, Hendon, N.W., was elected a Fellow, Dr. Franz Ritter von Hauer, of Vienna, a Foreign Member, and M. Henri Coquand, of Marseilles, a Foreign Correspondent of the Society.

The following communications were read :—

1. The following letter from the British Embassy at Copenhagen, transmitted by Earl Granville :—

Copenhagen, Oct. 10, 1871.

My Lord,—Two Swedish-Government vessels have lately visited this port, having on board a scientific commission which has just returned from an expedition to the coast of Greenland. They brought with them a number of aërolites which had been found on the coast upon the surface of the ground. These aërolites are all of the iron class, and consist of masses of what is called meteoric iron, of various sizes, the largest weighing no less than 25 tons.

As these curiosities were discovered in Greenland, one of them, the second in size, has been presented by the discoverers to the Danish Government, and has been placed in the arsenal in this city.

I have, &c.
(Signed) Charles Lennox Wyke.

Discussion.

Mr. David Forbes having recently returned from Stockholm, where he had the opportunity of examining these remarkable masses of native iron, took the opportunity of stating that they had been first discovered last year by the Swedish arctic expedition, which brought back several blocks of considerable size, which had been found on the coast of Greenland. The expedition of this year, however, has just succeeded in bringing back more than twenty additional specimens, amongst which two were of enormous size. The largest, weighing more than 49,000 Swedish pounds, or about 21 tons English, with a maximum sectional area of about 42 square feet, is now placed in the hall of the Royal Academy of Stockholm; whilst, as a compliment to Denmark, on whose territory they were found, the second largest, weighing 20,000 lbs., or about 9 tons, has been presented to the Museum of Copenhagen.

Several of these specimens have been submitted to chemical analysis, which proved them to contain nearly 5 per cent. of nickel, with from 1 to 2 per cent. of carbon, and to be quite identical, in chemical composition, with many aërolites of known meteoric origin. When polished and etched by acids, the surface of these masses of metallic iron shows the peculiar figures or markings usually considered characteristic of native iron of meteoric origin.

The masses themselves were discovered lying loose on the shore, but immediately resting upon basaltic rocks (probably of Miocene age), in which they appeared to have originally been imbedded; and not only have fragments of similar iron been met with in the basalt, but the basalt itself, upon being examined, is found to contain minute particles of metallic iron, identical in chemical composition with that of the large masses themselves, whilst some of the masses of native iron are observed to enclose fragments of the basalt.

As the chemical composition and mineralogical character of these masses of native iron are quite different from those of any iron of terrestrial origin, and altogether identical with those of undoubted meteoric iron, Professor Nordenskjöld regards them as aërolites, and accounts for their occurrence in the basalt by supposing that they proceeded from a shower of meteorites which had fallen down and buried themselves in the molten basalt during an eruption in the Miocene period.

Notwithstanding that these masses of metallic iron were found lying on the shore between the ebb and flow of tide, it has been found, upon their removal to Stockholm, that they perish with extraordinary rapidity, breaking up rapidly and falling to a fine powder. Attempts to preserve them by covering them with a coating of varnish have as yet proved unsuccessful; and it is actually proposed to preserve them from destruction by keeping them in a tank of alcohol.

Mr. Maskelyne stated that the British Museum already possessed a specimen of this native iron, and accounted for its rapid destruction on exposure by the absorption of chlorine from terrestrial sources, which brought about the formation of ferrous chloride. This was particularly marked in the case of the great Melbourne meteorite in the British Museum. He had succeeded in protecting this, as well as the Greenland specimen, by coating them externally, after previously heating them gently, with a varnish made of shellac dissolved in nearly absolute alcohol. He considered it probable that a meteoric mass falling with immense velocity might so shatter itself as to cause some of its fragments to enclose fragments of basalt, and even to impregnate the neighbouring mass of basalt with minute particles of the metallic iron; but he considered the question of meteoric origin could only be decided by examining the same mass of basalt at some greater distance from the stones themselves, so as to prove whether the presence of such metallic iron was actually characteristic of the entire mass of the rock.

Prof. Ramsay referred to the general nature of meteorites and to their mineral relationship to the planetary bodies, and remarked that, supposing the earth to have in part an elementary metallic core, eruptive igneous matter might occasionally bring native iron to the surface.

Mr. Daintree mentioned that he had been present at the exhumation of the Melbourne meteorite, and that at that time there was little or no trace of any formation of ferrous chloride, the external crust on the meteorite being not above $\frac{1}{32}$ inch in thickness.

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2. *On the* Diamond-gravels *of the* Vaal River, South Africa. By George W. Stow, Esq., of Queenstown, Cape Colony.

(Communicated, with Notes and Descriptions of the Specimens, by Prof T. Rupert Jones, F.G.S.*)

[With a Map, Pl. I.]

Contents.

Geographical features.—In travelling from the colony to the diamond-fields on the banks of the Vaal, the last shales similar to those of the Great Stormberg basin are met with at a short distance from

* In his letter of July 6th, 1871, requesting that I would name the specimens which he sent with this paper, Mr. Stow alludes to my paper "On the Diamond Fields of South Africa" in the 'Geological Magazine' for February 1871, as instigating him to collect exact information and verified specimens from trustworthy observers, with whom he was in frequent communication, without treating of any previously published accounts of the district. How far in all essential points the actual sections now brought forward by Mr. Stow substantiate the

the north bank of the Orange River, between Bethulie and Jager's Fontein. The sandstones continue beyond the shales (just as we find them on the southern or Great-Winterberg boundary of the same basin), and are visible in the ridges in the direction of Albania, to the north, and of Hopetown, to the south of the same river.

At a drift (ford) on the Reit River, a short distance beyond Jager's Fontein, a mass of rock, which has been termed "clay-slate," makes its appearance. It is of a dark blue slate-colour, and is said to break with a slaty fracture. It is possible that this may be a schist more ancient and indurated than the shales of the Stormberg formation. Beyond this the greater part of the country is covered with calcareous tufa, on which in some places is a reddish sandy soil, about 2 feet thick. The ground is traversed by numerous dykes, and by other slight ridges which seem to be composed of metamorphic rocks. On a near approach to the Vaal River the direction of these ridges can be easily traced; and they all appear to trend E.S.E.–W.N.W. In many places quartz-reefs run parallel with the dykes, their thickness varying from a few inches to 15 or 16 feet. No satisfactory conclusion, however, can be arrived at with regard to the basement rocks which intervene between Jager's Fontein and Pniel, except that none equivalent to those met with in the upper portion of the Stormberg-basin are to be found there. This part of the country, therefore, in all probability formed a portion of the northern or north-eastern boundary of the great sandstone and shale-system of the Stormberg. (See the paper by Mr. Stow, read before the Geol. Soc. Dec. 7, 1870, Q. J. G. S. vol. xxvii. p. 523.)

The immense extent of the diamond-deposits seems to be most clearly proved by the widely separated localities in which they have been found (see Map, Pl. I.). Taking Pniel as a central point, we find that they have been discovered (July 1871) not only at Jager's Fontein, a place nearly 96 miles on the southern side of the Vaal, but also at Mamusa, 75 miles beyond it. At this latter place a diamond upwards of 70 carats in weight was picked up on the surface. How much further these deposits may extend in the same direction is not known; but even this distance gives a breadth of 171 miles. The diamond-bearing country already ascertained stretches down the Vaal River for a distance of 110 miles, to a spot considerably below its junction with the Nu Gariep, or Orange River; whilst, above Pniel, diamonds have been found at a considerable number of places as far as Bloemhof, 102 miles further up the stream; and the last reports (July 1871) state that diamonds have been discovered at least 100 miles nearer the sources of the river, a distance of quite 312 miles from the most southern point previously mentioned.

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hypothesis advanced in the 'Geological Magazine,' will be found on comparing these papers. I must add that a great store of useful information about the diamond and the geology of diamond-fields in Australia, India, Brazil, and elsewhere, has been brought together by the Rev. W. B. Clark, M.A., F.G.S., Vice-President of the Royal Society of New South Wales, in his Anniversary Address to that body on May 25, 1870 (8vo, Sydney, 1871).—T. R. J.

In the accompanying Map (Pl. I.), which shows the Vaal River from the Plaatberg to its junction with the Reit River, all the localities where the diggers are most thickly congregated are indicated.

My friend Mr J. Graham, who has furnished me with the results of some observations he made on the level of the river, found by the aneroid that its fall was exceedingly small. Between Hebron and Klip Drift, a distance, along the course of the river, of more than 25 miles, it was only 22 feet. The stream is divided into long level reaches; and these in most cases are joined by a succession of small rapids. Three of those below Pniel are marked as Nos. 1, 2, and 3, on the map. The sinuosities of the river are very remarkable.

Whatever may have been the agency that occasioned the vast accumulations of gravel and boulders that we have to treat of, it must have been something more powerful than a current like that of the present Vaal.

The country to the south of the river consists of immense gently undulating flats, with scarcely any eminences worthy of being called hills. South of the Plaatberg the only elevation forming a range is between Bult-Fontein and Robinson's; and this only rises to a height of 400 or 500 feet.

A large portion of the country to the south of the Vaal is covered, as has been mentioned, with calcareous tufa, hidden in many places by a thin coating of light sandy soil, just sufficient to support a somewhat scanty herbage. Local depressions in the flats are very common; and most of these have no outlets to any lower level, although the drainage of a large extent of land slopes from every side towards them. In colonial phraseology they are styled "Braak-Pans." The origin of the depressions has yet to be explained; but the water of the "pans" appears to be due to its accumulation after heavy rains in these hollows. This is again rapidly evaporated in dry seasons, and leaves the soil impregnated with the saline particles dissolved and carried down thither from the higher slopes by the rain-water. The water, from the peculiar formation of the country just alluded to, has no other means of escape; thus the constant addition during a long course of ages has had such a sterilizing effect that the growth of all vegetation in the central portion, or "pan," is prevented by the extreme brackishness of the soil. Some of these "pans" are of large size—from 2 to 3 miles in length. Du Toit's Pan is one of this description. Between Jacobsdal and the Campbell-grounds there are two such salt-pans. About twelve years ago one of these ceased yielding salt, and continued in the same state for ten years; but during the last two years it has recommenced depositing a large quantity of saline matter.

Occurrence and geological place of the Diamonds.—Diamonds, up to the present time, have been found principally:—

1st. In an unstratified gravelly drift, containing immense numbers of huge boulders, with a red, clayey, ferruginous or ochreous matrix. Pniel is an example of this kind.

2nd. Unstratified gravel, with boulders most irregularly interspersed throughout, bound together with a calcareous cement; as is the case at Hebron and Diamondia (figs. 1 & 2, *c*).

These gravels, wherever found, contain large quantities of small fragments of fossil wood.

3rd. Irregularly stratified gravelly clays of various colours. Some of these also contain irregular patches of boulders. Examples of these are met with at Hebron and Diamondia (fig. 2).

4th. A pebbly drift, without large boulders, and bound together by a red ferruginous and rather clayey matrix. This is the case at Jager's Fontein.

5th. A gravelly sand of different shades of colour; the upper generally white, with irregularly interspersed boulders. This deposit is rather contorted in some places, and is found at a much lower level than the others.

Section I. I have not been able to procure many sections. One of them (fig. 1) comprises Natal Kopje, Cawood's Hope, and Gong-Gong; from all of which places many diamonds have been procured.

Natal Kopje.—On the summit of Natal Kopje there is a dark blue gravelly clay, with boulders (1); below this is a yellowish clay, intermixed with calcareous tufa (2); and beneath this is a reddish, ochreous, gravelly clay (3). These clays are very irregular in thickness, altering very much in a short distance; their total thickness varies from 2 to 4 feet. The largest diamonds (up to the present date, July 1871) have been here found within a couple of feet of the surface.

Below these beds is a great deposit of gravel (*d*). Its true thickness has not been ascertained; but shafts have been sunk into it for upwards of 30 feet without reaching the bottom; it is probably much thicker. It contains multitudes of pebbles of the various rocks found in the diamond-deposits. The peculiar shape, rather flat and oval, which many of them have, has caused the diggers to name them "kidney-stones;" they are thickly packed together in some portions of the gravel.

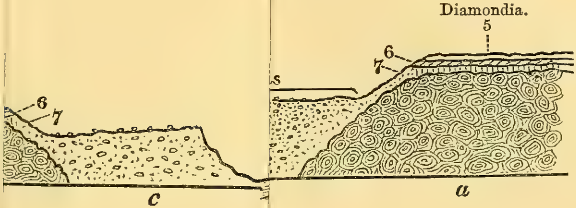
Upon what rocks this deposit rests is not known; but connected immediately with it is a subterranean escarpment of a rock (*a*) called by the diggers "rotten-stone" ("decomposed felspathic trap," Jones*), which they describe as a kind of "cone-within-cone," decomposed, rotten sandstone, breaking up in concentric layers, with hard, firm nuclei, resembling boulders. A shaft has been sunk down the face of this underground precipice for upwards of 30 feet, as shown in the section (fig. 1). Dense patches of such large pebbles as are found in the gravel seem to be massed along its front. This rock slopes off towards the land side, and is there covered with gravel (*e*), and boulders are spread over the surface. This gravel is about 2 feet thick; as yet no diamonds have been found in it.

Cawood's Hope.—Joining the Natal Kopje at rather a lower level, are two smaller kopjes, composed of a deposit similar to that found in the Natal Kopje. At the foot of a small ravine leading from these

* "Notes on specimens from Klip Drift and Pniel, by Prof. Rupert Jones," Mining Journal, March 4, 1871, p. 190.—T. R. J.

[*To face* page 6.

Fig. 2.—*Section*



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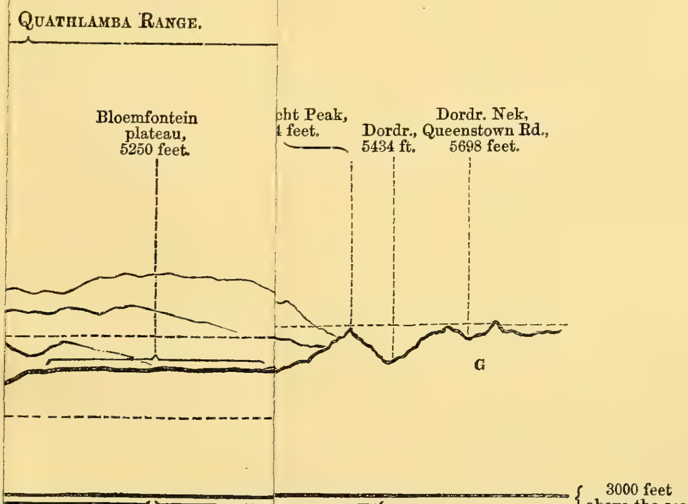

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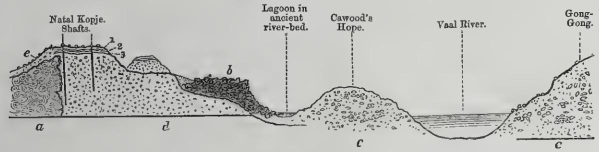
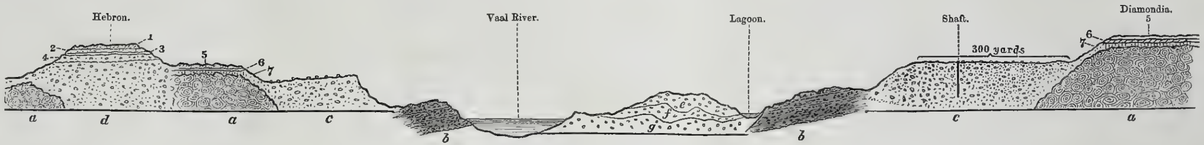
Fig. 1.—*Section of the Diamantiferous Deposits at Natal Kopje, Cawood's Hope, and Gong-Gong.* (Distance about 2200 yards.)



1. Dark blue, slate-coloured, gravelly clay, with boulders.
2. Yellowish clay, with patches of calcareous tufa.
3. Bright red gravelly clay.

a. "Rotten-stone." [Decomposed felspathic amygdaloid?—T. R. J.]
b. Metamorphic (?) rocks, covered with immense boulders.
c. Red, unstratified, clayey gravel, with many boulders, and containing numerous worn fragments of fossil wood.
d. Unstratified gravel, containing "kidney-stones."
e. Gravel, about 2 feet; no diamonds found.

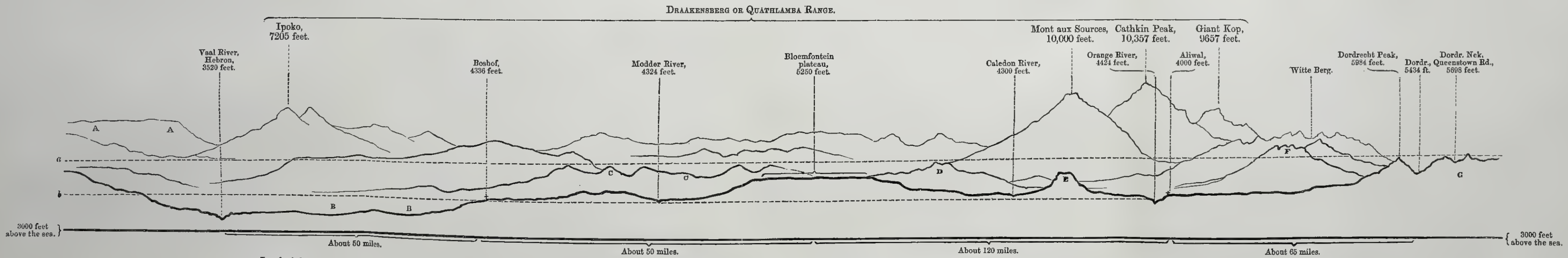
Fig. 2.—*Section of the Diamantiferous Deposits on the banks of the Vaal, from Hebron to Diamondia.* (Distance about 3000 yards.)



1. Black gravelly soil, containing diamonds.
2. Reddish gravelly clay.
3. Intense red, ochreous, gravelly clay.
[No diamonds have yet been found in Nos. 2 and 3.]
4. Portion of *d* that has been examined and found to contain diamonds.
5. Blue, slate-coloured, gravelly clay, with boulders. Diamonds.
6. Yellow clay, with irregular patches of calcareous tufa. Diamonds.
7. Reddish, ochreous, gravelly clay. Diamonds.
[Nos. 5, 6, and 7 are superimposed upon *a*, and the inequalities of the surface of the latter form "pockets," in which numerous diamonds have been found. All three contain diamonds; their total thickness is from 2 to 6 feet.]

a. "Rotten-stone." [Decomposed felspathic amygdaloid?—T. R. J.]
b. Metamorphic (?) rocks, forming the floor of the river-valley.
c. Red gravel, unstratified, containing boulders, diamonds, fossil wood, and one fragment of fossil bone. [This gravel becomes paler on sinking into it, until it is almost white; some portions near the centre of the shaft are bound together by a calcareous cement.]
d. Cemented gravel and boulders, similar to the middle portions of *c*.
e. White, *f.* Yellow, *g.* Bluish } sandy gravel, with boulders, in which few diamonds have been found, except on the surface.

Fig. 4.—*Panoramic Sketch showing the relative heights from the Stormberg, through Bloemfontein to Hebron on the Vaal River; also of the sources of the Ky Gariep (Vaal) and Nu Gariep (Orange) Rivers.*



a. Level of the Dordrecht mountains.
b. Level of Aliwal.

AA. An elevated plateau, north of the Vaal River, of which the Magalies Berg is the culminating ridge. Height nearly 7000 feet.

BB. Depressions in which "Brak-pans" are formed.
CC. Witte Bergen, Orange-River Free State. Height unknown.
D. Maluti Bergen.

E. Assvogel Kop.
F. Washbank.
G. Stormberg.

kopjes is a dry river-bed, with a small pool (or "lagoon," as it is termed at the diamond-fields) near its centre. Along its southern bank are accumulations of exceedingly large boulders piled up upon rocks that have been scarped in many places by the action of the current. In very high floods a portion of the water still flows through this ancient channel; and a number of trees, such as grow along the sides of the present course of the river, still fringe its margin.

Between this and the river itself is another great deposit of gravel (Cawood's Hope) rising about 30 feet above the level of the stream. It seems as if at one time it must have been continuous with the gravel mass on the northern side, now forming the Gong-Gong diggings. In that case, the river must have flowed along the ancient water-course alluded to, until it cut out for itself the new and more direct channel it now occupies. This Cawood's Hope accumulation of gravel is bound together by a reddish matrix, similar to that at Pniel. It is unstratified, and contains many interspersed boulders. An important fact connected with it, as well as with most of the diamantiferous gravels, is that in it are numerous worn fragments of fossil wood, very similar to that found in the forest-zones of the Karoo formation in the Stormberg and Draakensberg. A water-worn fragment of fossil bone has also been discovered, and fortunately preserved. I shall again allude to these interesting facts before closing the paper.

The depth of the gravel below the bed of the river here cannot be very great; for immediately above this place there are some small rapids, caused by the rocks crossing the stream; and near the middle a little island has been formed, principally of gravelly clay; but no diamonds have been found in it.

Gong-Gong.—Abutting immediately on the northern bank of the river are the Gong-Gong diggings. These are spread over a deposit of gravel, extending along the banks of the river for a considerable distance. Its highest point rises some 50 feet above the level of the water. It is a very red gravel, intermixed with irregular patches of boulders; all bound together with a clayey matrix, very similar to that of the Pniel Kopje. The gravel contains polished and worn specimens of various rocks. See "No. 1" in Appendix.

Section II. *The Deposits at Klip Drift and Pniel**.—Pniel Kopje is nearly 150 feet above the river; a large portion of it is composed of a vast accumulation of enormous boulders intermixed with an ochreous and very clayey matrix. The intercalated gravel is very similar to that found in the diamond-bearing deposits at Gong-Gong &c., the great difference being the preponderance of immense and thickly interspersed boulders of various kinds of rock. The pebbles it contains are shown by the specimens sent. See Nos. 3, 4, 5, 6, from Pniel, and Nos. 7, 8, 9, from Klip Drift, in the Appendix.

These were procured from one of the "cradles," without sorting,

* For Mr. E. T. Cooper's map and description of this locality, see the 'Mining Journal,' March 4, 1871, p. 190.—T. R. J.

and therefore exhibit more perfectly the proportion of the several kinds. Garnets are unequally scattered throughout the mass. Fragments of fossil wood are frequently met with. A great many of the pebbles are found in a fragmentary condition, owing, probably, to the action of the large boulders with which they are associated. Shafts have been sunk into these deposits to a depth of more than 30 feet.

In some places immediately below this gravel there is a thin layer (a few inches thick) of a very fine tough yellowish clay, almost like an ochre; and below this are the ancient rocks that form the floor of the valley of the Vaal.

This boulder-gravel extends for a considerable distance, almost parallel with the course of the river, forming a terrace-like ridge, which finally slopes down towards the bank. This is the deposit in which a large number of diamonds have been found; the largest have all been within 2 feet of the surface.

The same gravel is found on the opposite side of the river at Klip Drift, but in much smaller quantity. The component pebbles are shown by those sent. See Nos. 7, 8, 9, Appendix.

Fragments of fossil wood are more plentiful here and at Hebron than in any other portion of the diamond-deposits yet examined.

The upper portion of the gravel, which diminishes in some places to a thickness of 5 feet, and in others even to a single foot, is placed upon a thin laminated layer, from 6 to 8 inches thick, spread over the floor of many of the "claims," adapting itself to the inequalities of the deposit on which it lies. On breaking through it, a yellowish and rather ochreous clay is found; and, although shafts of 10 feet have been sunk into it, its thickness is not at present known. These deposits evidently rest upon the rocks before mentioned.

Islands in the river here are of frequent occurrence: most of them are composed of gravel, which is apparently of a far more recent origin than that of the Kopjes and the terrace-like accumulations of Gong-Gong and Pniel. Some of them have trees growing them, as the island near the last-mentioned place. Several of these islands have been examined for diamonds, but with little success. The rapids, which also are very numerous, seem to be caused by felspathic dykes crossing the bed of the river.

Section III. At a distance of about twenty-four or twenty-five miles further up the river are the Hebron diggings. I have been able to obtain a more complete section of this locality than of the others. In this there is an evident sequence in the gravels; and it throws considerable light upon the true position of those we have been considering.

Hebron and Diamondia.—This section (fig. 2), commencing at Diamondia, passes through the "lagoon" in the ancient river-bed (see Map), then shows the lower gravel, thence crosses the river to the upper kopjes on the Hebron side.

The uppermost deposits are those numbered Nos. 5, 6, and 7.

No. 5 is a very dark blue, slate-coloured, gravelly clay, with irregularly interspersed boulders; below this is No. 6, a yellow clay, thickly mottled with patches of calcareous tufa, which has evidently infiltrated into its substance; and below this is No. 7, a reddish, ochreous, gravelly clay. These rest upon the same rock ("rottenstone") as that met with in the Natal Kopje. The hollows of its surface are termed "pockets" by the diggers; and in these the finest diamonds are said to have been found.

These gravelly clays seem to be the equivalents of those found above the great gravel-deposit at the above-mentioned kopje. They are also found on the opposite side of the river, at Diamondia, capping the same kind of rock. There are other beds of a very similar character, resting upon the highest of the Hebron gravels (see fig. 2). Continuing this section, a vast accumulation of boulder-gravel (*c*) is found at rather a lower level. Its width is 300 or 400 yards; shafts have been sunk to a depth of between 30 and 40 feet without reaching its bottom. It is quite unstratified; and large boulders are confusedly mixed with it. The upper portion is of a red colour; but, on digging into it, it gradually becomes lighter below, and more compact. In some parts it has a calcareous cement.

On the Hebron side there is also another great deposit of boulder-gravel, at rather a higher level (see fig. 2). This seems to have almost entirely the same cement or matrix as those just mentioned.

All these gravels contain diamonds, as well as numerous fragments of fossil wood (the specimens sent were obtained at *c*, on the Diamondia side). Some fragments of fossil bone, found at the same place, have been unfortunately lost; but, from the description given, they must have been water-worn fragments of reptilian remains *. The pebbles contained in the gravel are illustrated by the specimens sent. See Nos. 10 & 11, from Hebron, and No. 12, from Diamondia, in the APPENDIX.

The reddish colour of the upper portions of the gravels at *c*, *c*, seems to be most probably due to infiltration from above, as, on penetrating into them, the colour soon becomes paler, and gradually disappears. The same may also be said of the lower gravels that have a calcareous cement.

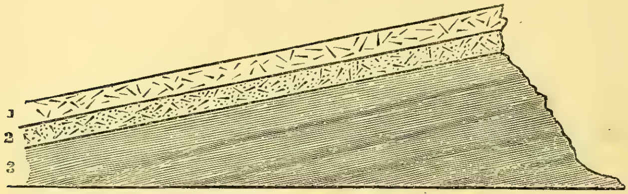
From the lie of the strata, it is probable that these gravels, *c*, *c*, rest upon the ancient rocks marked *b*, *b*; but, for want of definite information, I have been unable to show their exact position with reference to each other. These lower rocks are described by some of my friends as "metamorphic" and distinctly showing evidence of stratification, with a dip of about 7° to W.N.W., towards the river on the Diamondia side, and from it on the Hebron side †.

* I have since seen one of these specimens; it was probably a metapodal bone, 1½ by 1 inch, very much polished. July 6, 1871.

† I cannot help thinking that the so-called "clay-slate" of the Vaal is very similar to, if not identical with, rocks of the same character in the lower portion of the Great-Fish-River valley, and that an ancient system of metamorphic rocks, most probably connected with those of the Vaal, underlies the strata of the Stormberg basin; indeed, judging from what I have seen in some of the exten-

Those at the former locality are smooth and *polished*, and, where exposed to the action of the weather, black on the outer surface; but where covered, of a reddish hue. They are close, hard, and compact, with a felspathic (?) character. At another spot, a section of them is given as follows (fig. 3):—

Fig. 3.—*Section of Supposed Metamorphic Rocks on the Vaal River.*



1. Whitish quartz.
2. Quartzose rock.
3. Rock similar to *b* in the large section (fig. 2).

It appears highly probable that at one time these rocks from *b* to *b* (see the Section, fig. 2) have been eroded into a wide trough, in which the more recent gravels, *e*, *f*, and *g*, have been laid down. These gravels are evidently of a more recent origin than those at the higher levels, and are most probably composed of materials from the older gravels. The gravel and boulders are intermingled in the most confused manner; and the several bands have irregular lines of bedding, and are rather contorted, appearing different from what might have been expected if laid down simply by fluvial action. This deposit was at one time very extensive in this locality, stretching across the present course of the river, and for a considerable distance along the bank of the Hebron side (see Map, Pl. I.). The stream, before it cut the new channel through these gravels, must have occupied an ancient river-bed, which, like the one at Cawood's Hope (p. 6), is now left dry, and traversed by flowing water only at the time of a very high flood.

Du Toit's Pan.—With regard to Du Toit's Pan, which is rapidly becoming the chief centre of attraction to the diggers, I have not been able to obtain a trustworthy section, nor sufficient data to form a decided opinion upon the diamantiferous deposits in that

sive sections I have lately made, it crops up through them; or, rather, the denudation has been so great in several places that it is exposed. This seems to be corroborated by information given to me a few days ago by Mr. H. Southey, who says that in the district of Middleberg, near the Rhenosterberg, there is a strip of country, stretching from the Orange River, with "pans" of exactly the same character as those between the Modder and Vaal, and that at two of them (Groote Fontein and Klip Riff, between Middleberg and Craddock) numerous garnets have been picked up which seemed to him to be similar to those from Du Toit's Pan.—G. W. S., July 6, 1871.

locality*. It is situated about twelve miles from the river, and is about 100 feet higher than Pniel. The boulder-clays and gravels which are found nearer the course of the river appear to be wanting here. In many places the uppermost stratum is a red marl, largely impregnated with calcareous tufa; in others, the tufa takes the place of the marl. Below this is a stiff red clay, called "Braakgrond" (fallow ground). Both these vary very much in thickness.

Beneath the clay is a deposit which has been described as a decomposed trappean (?) rock. This is full of *angular fragments* of many of the constituents of the other deposits, besides diamonds and innumerable small garnets. (See Nos. 13, 14, 15, in Appendix.) This stratum is twenty feet thick, and rests upon "clay-slate"(?). It has been described as out-poured volcanic rock, now decomposed; and the pan itself has been termed a "crater"; but this idea does not receive the least support from an examination of the deposit itself. Mr. Ella informs me that the floor of the pan is composed entirely of "clay-slate" [hard shale ?], and that in it no fissures can be traced through which an out-pouring could have taken place. The so-called "volcanic-ash" is merely a dark soil, strongly impregnated with calcareous tufa. The sharp, angular, fragmentary condition of most of the rocks found in the deposit above mentioned seems to indicate that the stratum in which they are now found could not have been their original matrix. Had it once been a molten mass, as has been suggested, these imbedded fragments would certainly have borne evidence of the intense heat to which they had been subjected. Again, in some portions of the diggings at the Pan these strata are said to bear unmistakable testimony of their being sedimentary rocks. My brother informs me that he has found leaf-impressions and plant-stems: unfortunately none of these have been preserved.

At a depth of seven feet from the surface, at one spot fragments of Ostrich egg-shells and some Bushmen-beads, made of the same substance, have been found, intermixed with a small univalve shell. To explain the position in which these were discovered, a suggestion has been ventured that, as the molten (?) mass contracted in cooling, cracks and fissures were formed, and a subsequent flow of water has washed these remains into the openings thus caused, and there buried them. Ancient relics of the same kind were found even at a greater depth at Jager's Fontein; and I have seen similar traces of the primitive race of Bushmen obtained in other parts of the country, from beds of gravel fifteen feet below the surface; I cannot, therefore, understand how the hypothesis above given can be supported†.

The characteristics of the Du-Toit's Pan deposits differing greatly from those nearer the river, no satisfactory explanation can be given until a careful analysis has been made of them.

Inferences.—In examining the foregoing sections of the gravels, it

* See Mr. G. S. Higson's notes on its shales and dykes, quoted in the Geol. Mag. February 1871, p. 52.—T. R. J.

† A small piece of Ostrich egg-shell, and several small flakes of agate, one of which has been used, probably in making beads, or perforated disks, of egg-shell, was found by me on examining a parcel of this gravel from Du Toit's Pan.—T. R. J.

seems evident that the diamantiferous deposits of the Vaal are not the result of any single or abrupt operation of nature, as some have suggested, either in the shape of some "great débâcle," or volcanic eruption, but rather that, for some enormous period of time, there were long-continued causes at work, occasioning a distinct sequence in the different wide-spread accumulations of boulder-drift, clays, and gravels of which they are composed.

At Hebron and Diamondia this is clearly the case: there we find, first, the unstratified cemented gravel and boulders, as shown at *d*, in fig. 2; the terrace-like deposits at *c*, *c*, were deposited probably at the close of the same period. Then followed the boulders and gravelly clays, marked Nos. 1, 2, 3, 5, 6, and 7. All these in their turn have undergone great denudation, the lateral drainage from the more level country having divided them into separate terrace-like mounds and isolated kopjes, the intermediate portions having been carried away, and a rearrangement of portions of the gravels (*e*, *f*, and *g*) having taken place at a lower level in the ancient trough of the old rocks *b*, *b*. These latter gravels are much more sandy than the more ancient drifts, large portions of their clayey elements having necessarily been washed out of them during the period of readjustment. Finally, this last deposit (*e*, *f*, and *g*) has been cut through by the river in forming its present channel.

The question now arises, Were the more ancient boulder-gravels derived from a local source, or have they travelled from a distance? And, if so, what is the probable direction whence they came? and by what agency were they transported to the localities where they now are?

Although the original locality of the true matrix of the diamonds found in them has not been discovered, still there can be little doubt that a large portion of the constituents of these deposits has come from great distances.

At this point, the tell-tale fragments of fossil wood, worn and polished as they are, become most interesting and valuable evidence. Zones of fossil wood extend almost the entire length of the Stormberg*; and magnificent specimens are found in many places on the northern side of these mountains. I have been told, by the Hon. Theophilus Shepstone, that, in his journeys through Kaffirland, he has traced the existence of large quantities of fossil wood along the Quathlamba or Draakensberg range to Natal. I am not aware, however, that these zones have been found stretching to any great distance northward, or in a north-westerly direction from these ranges, towards that part of the diamond-bearing fields now under consideration.

Place of Origin of the Drifts.—It was always believed in the Cape Colony that the country rose towards the far interior in a succession of steps; but the results of Mr. Graham's barometrical observations show this to be, to a certain extent, incorrect. From the coast to the ridge of the Stormberg, however, it holds good, and along a line within a certain distance of the western face of these mountains:

* Quart. Journ. Geol. Soc. vol. xxvii. p. 523 &c.—T. R. J.

thus, proceeding from Dordrecht to Aliwal, we find the level of the river at the latter place upwards of 4200 feet above the sea. Thence to Bloemfontein there is a continuous rise from one step to another, until the plateau upon which Bloemfontein is situated attains an altitude of upwards of 5000 feet; while the mountains forming the dividing ridge between the heads of the various tributaries that run into the Upper Nu Gariep, or Orange river, and those that empty themselves into the Indian Ocean rise to a height of upwards of 10,000 feet.

The same continues to be the case in proceeding still further northward, across the upper portions of the streams that flow into the Ky Gariep, or Vaal. The culminating point of that part of the Draakensberg which forms the boundary of the watershed of this river is 7200 feet; while the northern side of this same river-valley is bounded by an elevated plateau, called Hooge Veldt (fig. 4, A A), said to be, in portions near Magalies-Berg, nearly 7000 feet above the sea.

These elevated mountain-ranges, and the more level plateaux that are connected with them, form a vast but irregular semicircle, with an outline of upwards of 500 miles; and within these widely separated points all the drainage flows either into the Orange or the Vaal river: but the extent of the successive plateaux of *increasing* altitude is confined within an equally irregular line, running round the interior of this semicircle.

Beyond this line a vast denudation must have taken place, which has been no doubt one of the principal causes of the very considerable lowering of the level along these river-basins towards the west. This will perhaps be best explained, in the case of the Vaal, by a reference to the diagram that I have drawn to show the relative heights of the country (fig. 4). Here it will be seen that the plateau of Bloemfontein, together with the mountains with which it is associated, is the outer limit of the central portion of the elevated tract of country I have described, and extends between the basins of the two rivers. From this point towards the north-west, instead of rising step by step towards the interior, as has been supposed, the very reverse is the case. It gradually descends for about 100 miles, until at Klip Drift, on the banks of the Vaal, its level is 1750 feet below that of Bloemfontein, or some 3498 feet above the sea, an elevation of not 50 feet above that of Queenstown, which is 280 miles further to the south, and about forty miles south of the Stormberg.

The great distance between Klip Drift and Pniel and the sources of the Vaal River makes the difference of altitude almost imperceptible to the casual traveller, as the Likwa (or Upper Vaal), rising near the Ipoko, is 330 miles, and the head of the Klipstopel (or Kapok, that is, Snow River, as it is called by the Dutch) is 420 miles distant.

The very considerable difference in altitude between these different points is sufficient to show the immense amount of denudation that has taken place. The fall must, of course, be still greater at the junction of the two rivers, a distance of upwards of 100 miles below Pniel.

The agencies that have worked out the one basin have without doubt operated in the formation of the other, both being valleys of denudation; and the whole of such deposits as those found upon the lower plains, and along the banks of the rivers, must have originated within the boundary-line that has here been pointed out as the great watershed of the rivers running into the Atlantic and the Indian Ocean. It is therefore within this limit that we must seek for the origin of the diamantiferous gravels and other deposits of the Vaal.

Rocks and Fossils of the Upper Drainage-area.—Before proceeding, however, it will be well to consider the indications we possess of the character of some of the formations that form different portions of this outer boundary-line. The evidence in my possession is scanty, but of great interest. Commencing on the northern boundary, we find that in the Magalies Berg and Pretoria there are micaceous rocks, vastly different from those belonging to the great Dicynodon-formation of the Colony, consisting of and containing large quantities of mica, with ores of copper and lead, the latter, it is said, very abundant. See Nos. 19, 20, 21 in the APPENDIX.

From this spot to the sources of the Umzimvoobo, on the southern side of the Quathlamba, I have been unable to obtain rock-specimens; but from this last locality I was fortunate enough to secure several, collected by Mr. Whitmore from the gravels along the watercourses. See No. 22 in APPENDIX.

These form a most interesting collection, and might be easily mistaken, both from their shape and character, for some of the pebbles obtained from the diamond-bearing gravels of the Vaal.

From the Zeitza, a small stream rising in the same mountains, similar specimens were obtained (Nos. 23 & 24 in APPENDIX).

Also from the heads of the T'somo, a river rising among the branches of the mountains that form the junction of the Quathlamba and Stormberg ranges, rocks very similar to some of the fragments found in the valley of the Vaal. See Nos. 25, 26, and 27 in the APPENDIX.

Origin of the Gravels.—The conclusion to be drawn from the consideration of these facts taken collectively (the whole of these specimens being procured from *the southern side* of the mountains, from the northern side of which both the Orange and Vaal take their rise) is, I think, that zones of fossil wood are found stretching along these mountains, and that they contain rocks which are similar to many of those found in the Vaal-River gravels. It is therefore highly probable that the fragments of the fossils found in them, and of the various, yet very similar, rocks, have both come from the same source, namely the elevated ridge that forms the watershed of the rivers that flow into the two different oceans, and that during the vast denudation to which the strata have been subjected large portions have been carried away in the one or the other direction. On the north they have been promiscuously intermingled along the present river-valleys, in the unstratified gravels and other deposits described above. On the other hand, how near these rocks approach the diamond-deposits on the *northern* side, and what may be the exact position of the *original* matrix from which the diamonds were really derived, have yet to be determined.

Dr. Voysey, Geologist to the Trigonometrical Survey in Southern India, has stated "that the matrix of the diamonds produced in Southern India is the sandstone breccia of the clayslate formation." As some of the formations in India are closely allied to those of Southern Africa, it would be interesting to ascertain whether any rocks similar to those mentioned by Dr. Voysey are to be found either in the extensive range of the Quathlamba, or in any of its offshoots.

The same authority further states "that the diamonds found in the alluvial soil are derived from the débris of the above rock (sandstone breccia), and have been brought thither by some torrent or deluge, and that no modern or traditional inundation has reached to such an extent."

In considering the probable agency that has operated in Southern Africa in producing these vast accumulations of gravel, it may be asked, in the first place, have these gravels been laid down by common fluvial action, assisted and increased by floods and rain-storms, such as those at present in operation? The deluges of rain that sometimes accompany heavy thunderstorms in this country turn every stream, in every ravine, into a dangerous torrent, and the rivers into impetuous floods, that tear away every thing before them, and frequently discolour the sea for many miles with the floating sediment they have brought down with them. But in examining the results of these inundations—the deep and abrupt chasms they have worn, the *assorted* gravels they have left, the direction and position of the boulders, and the finely laminated mud or clay—there can be no mistaking the agency by which they were effected. With regard, however, to the diamantiferous deposits now under consideration, there are many characteristic features about them that cannot be satisfactorily accounted for by reference to such an agency. The extensive unstratified boulder-gravels, such as are found at Diamondia, Hebron, and many other places,—the unstratified gravelly drift, with clay and boulders, as at Pniel—irregular patches and mounds of boulders,—the boulder-clays, and the confused manner in which they are intermingled throughout the entire length of this river-valley, have made all whose opinions I have been able to obtain declare that such heterogeneous accumulations could not have been formed by South-African river-action under its present conditions. If laid down by this agent, the deposits would certainly have shown a greater regularity; the silt would have exhibited a regular interlamination of its clays, sand, or gravel as the case might be, such as may be found in the present deposits of the Fish river, in which are imbedded animal and other remains that tell of their recent origin. So also these vast accumulations, had the same conditions existed, would have contained organic remains indicating the period of their deposition; but no recent fossils have been found in these gravels, although thousands of diggers have been working at them for many months. Only large quantities of *worn* fragments of fossil wood and two or three pieces of fossil reptilian bones, all from the older formations, have been met with.

The fragments of pierced Ostrich egg-shells found at Du Toit's Pan, although of considerable antiquity, evidently belong to a far more recent deposit, and have been buried in the silt of a "Pan" or "Fontein," which was the drinking-place of some primitive tribe of Bushmen.

The absence of recent remains and the frequent fragments of ancient fossils are of great value in the history of some of these gravels. Again, the worn and *highly polished* surfaces of nearly all the fossils and pebbles, together with the *flattened* and *wedge-like* shape of many of them, are highly suggestive. Running water would have *rounded* them. And not only are the small pebbles highly polished *, but very many of the large boulders have their surfaces smoothed and polished. In the excitement of diamond-hunting, however, few have thought of looking for striæ or scratches upon any of them (see Postscript). Lastly, on the Diamondia side of the river, the rocks themselves marked *b* in the Section, fig. 2, have the same smoothed and rounded appearance.

The conclusions to be drawn from the foregoing facts appear to be these:—

1st. That large portions of the diamond-bearing gravels are not of local origin, but must have travelled long distances, gathering and carrying with them fragments of the various rocks over which they passed in every stage of their journey.

2nd. That, as many of their constituents are found in the Quathlamba or Draakensberg, it is highly probable that a large portion had its origin in that range, or in its northern offshoots.

3rd. That, although it has yet to be determined whether the fixed rocks that contain diamonds are to be found in the mountains mentioned, or whether these gems have been intermingled with the gravels at any intermediate stage of their passage downward to their present site, it seems certain, from the appearance of many of the diamonds discovered, that a large number must have travelled a considerable distance, and that the numerous broken ones have been fractured by the grinding power of the massive boulders with which they are so frequently associated.

4th. That the vast unstratified deposits, the promiscuous piling together and intermingling of boulders, the remarkable polish of many of them, the terrace-like mounds and accumulations, all evince physical conditions far different from those at present in operation; while the entire absence of all recent fossils in these gravels almost forces upon us the conviction that they must have

* This peculiar polish of pebbles and fossils is observed in Australia and elsewhere, as remarked by the Rev. W. B. Clarke, F.G.S., in his Address, Roy. Soc. N. S. Wales, May, 1870, who refers to drifting sand and silicated water as being probable agents under some circumstances.—T. R. J.

been laid down under circumstances inimical to animal and vegetable life; and these circumstances, judging from similar deposits in other countries, have been brought about by the action of *ice*.

5th. That such gravels as those marked E, F, and G, in Section, fig. 2, were probably rearranged from more ancient gravels in a trough eroded in the rocks forming the floor of the Vaal valley.

In compiling this paper I have been greatly indebted for notes and descriptions to Messrs. Shepstone, Donald, White, Kedger Tucker, Cronin, Key, Scott, Ella, Southey, Graham, Whitmore, and several other gentlemen.

Postscript, July 6, 1871.—Since writing the above, I have been informed by Mr. Tobin, who has travelled along the valley of the Vaal from the Draakensberg to Pniel, that he has traced agates along its entire course, and that at Harrismith, twenty-three miles on the Free-State side of the mountains, a very extensive zone of fossil wood makes its appearance. Mr. Tobin also showed me some sketches of the road over the Draakensberg, which reminded me forcibly of the peculiar rounded (glaciated) contours that I described in my former paper as noticeable in the Katberg*.

Lastly, Mr. George Gilfillan, who is at present on a visit to Queenstown, tells me that a short time ago he discovered near Pniel a large boulder with *striæ* distinctly marked upon it, and that since then he found at "Moonlight Rush" that almost every boulder in the gravels there has most unmistakable markings of the same kind upon one or more sides. This appears to me a most satisfactory and important discovery with regard to the deposits we have been considering, and one which must definitely settle the question as to the conditions under which many of them were laid down.

G. W. S.

Appendix.—Description *of* Specimens *sent by* Mr. Stow. By Prof. T. Rupert Jones, F.G.S.

In a letter, dated October 10, 1871, Mr. G. W. Stow states that, after a three week's visit to the Vaal-River Diamond-fields, he feels certain the description given of the diamond-gravels in the foregoing paper is correct, and that no other agency than that advocated in it could have formed the accumulation of boulder-drift, the river-deposits being distinct.

In determining the nature of these specimens, Thomas Davies, Esq., F.G.S., of the British Museum, has kindly given me his assistance.

No. 1. *From Gong-gong.* See page 7.

Washed, coarse, agate gravel†, containing:—

Veined Jasper, one pebble.

Yellow and white Quartz, several pebbles.

* See Quart. Journ. Geol. Soc. vol. xxvii. p. 539.

† A small dressed (?) fragment of rock-crystal was sent with this parcel.

Agate, various, and largely predominating; rounded and subangular, mostly polished or glazed.

No. 2. *From Cawood's Hope.* See page 6.

Two rolled pieces of fossil Wood.

No. 3. *From Pniel.* See page 7.

Washed agate gravel*, containing:—

Lydite, rounded (pebbles).

Jasper and Quartzite, subangular and much worn (more than in the gravel from Klip drift).

Fossil Wood, much rolled, one piece.

One fragment of Quartz, off a worn crystal.

Agate, various; subangular and rounded; largely predominating.

No. 4. *From Pniel.* See page 7.

Some unwashed ochreous agate gravel. (Not nearly so ochreous as some sent from the Klip-drift diggings by Mr. E. T. Cooper and Dr. G. Grey; 'Mining Journal,' March 4, 1871.)

No. 5. *From Pniel.* Page 7.

A small weathered subangular block of light-greenish Amygdaloidal Greenstone, weathering brown.

No. 6. *From Pniel.* Page 7.

Another, similar, but of a dull-greenish tint. Both are studded with chalcedonic Agates.

No. 7. *From Klip drift.* See page 7.

A freshly broken piece of a large, rough, angular, yellowish Agate of Chalcedony and Quartz, like that from Hebron.

Nos. 8 & 9. *From Klip-drift.* Page 7.

Washed, coarse, agate gravel†, containing:—

Lydite pebbles, few.

Jasper, some subangular pieces.

Micaceous Hæmatite, one fragment.

Quartz crystals; fresh, subangular, and rolled.

Agate, largely predominating; very various, including much green chalcedony; subangular and rolled‡. Some of the agate pebbles are very much water-worn, some glazed; and some pebbles have been broken and reglazed.

No. 10. *From Hebron.* Page 9.

A freshly broken yellowish Agate, like that from Klip-drift (No. 7).

No. 11. *From Hebron.* Page 9.

Washed, coarse, agate gravel§, containing:—

One small, very round pebble of Lydite‖.

* One small fragment of Garnet was sent with this parcel.

† One small subangular piece of Garnet was sent in this parcel.

‡ Many of the roundest of the agate pebbles in these gravels of the Vaal are globular agates (chalcedonic nuclei of the amygdaloids) not much rolled.

§ A few subangular and rolled small Garnets accompanied this parcel.

‖ As in other cases, the Lydite is here much rolled by travel, and bears evidence that some of the gravel (and perhaps the Diamond) has been derived from the metamorphic rocks.

Quartz-crystals, fresh, probably from a geode.
Agate, various, predominating largely; angular, subangular, and rounded: many pebbles glazed.

No. 12. *From Diamondia.* See page 9.

Washed, coarse, agate gravel*, containing:—

Rather large pebbles of various Jaspers (red &c.), some glazed.
A subangular water-worn fragment of Crocidolite-rock (the Crocidolite, altered to fibrous quartz, interlaminated with dense siliceous bands).
Small subangular fragments of Sandstone.
Quartz crystals, both fresh and rounded.
One pebble of Agate-breccia.
Agate, very various and abundant; subangular and rounded; rather large; some pebbles highly glazed.

Nos. 13, 14, 15. *From Du Toit's Pan.* See page 11.

1. Not washed. A small quantity of drab-coloured, calcareous, earthy, coarse sand.
2. Washed graved (from a "cradle" after sifting†), white and black, containing:—

Calcareous tufa and Calcite, very abundant; subangular and rounded: supplying the largest lumps (not larger than walnuts) in the gravel, every thing else being of much smaller size.
Zeolite; angular fragments, rare.
Felspar (Orthoclase and Albite?); angular fragments, few.
Magnesian Mica, somewhat decomposed; flakes, preserving more or less of the crystal form, not rare.
Steatite; pilular, in small concretionary globules‡; common.
Soapstone; three angular pieces.
Chlorite (Clinochlore) schist§; one fresh fragment.
Fibrous Talc-rock§ (altered Anthophyllite?); lustrous, bronze-yellow; three subangular pieces.
Green Actinolite-schist§; three subangular pieces.
Dark-grey soapy shale; three freshly broken pieces.
Magnetite; some small subangular fragments.
Ilmenite§, very abundant; fresh-broken, subangular, and rounded.
Garnet, including Pyrope and Cinnamon-stone, very abundant; fresh and subangular.
Diopside (including Smaragdite (?) and Enstatite), abundant; fresh and subangular. Also Olivine (?).
Natrolite, broken prismatic crystals; not rare.

* A few fragments of Garnet, fresh and subangular, came with this parcel.

† A 39-carat diamond was found among this lot before it was sent.

‡ Prof. Tennant has received from Du Toit's Pan a small slab of greenish steatitic rock, composed of similar globules in a green matrix—also some Tourmaline and Zircon (rare), with decomposed felspathic, talcose, and micaceous rocks.

§ Bearing evidence of the presence of metamorphic rocks.

Hepatic Pyrites †, and small fragments of Hæmatite, rolled.

Agate, various, not nearly so abundant as the Ilmenite and some other minerals; subangular and rounded, mostly very small and very much water-worn; some of the little pebbles highly glazed. Also some few fresh fragments, including small waste flakes and a little implement used by the Bushmen in making perforated disks or beads of Ostrich egg-shell.

A group of small Quartz crystals (some peculiar), including Amethyst, from a vein or a geode.

A small bit of Ostrich egg-shell.

No. 16. *From Jager's Fontein.* Page 11.

A piece of Ostrich egg-shell.

No. 17. *On the Orange River, thirty-six miles below Hopetown.* [Probably the "Asbestos Mountains" of Mr. G. A. Bain's Map, Geol. Trans. ser. 2, vol. vii. pl. xxi.]

Crocidolite, partly decomposed; deep amber in colour, passing here and there into blue.

No. 17*. *From the same place.*

Seam of altered Crocidolite (deep yellow), with parallel layers of siliceous Ironstone (dull yellowish-brown Jasper), and of Magnetite, attached.

No. 18. *From the same place.*

A piece of a dull brownish-grey chalcedonic seam associated with the altered Crocidolite.

Nos. 19, 20, 21. *From Pretoria, Magaliesberg.* Page 14.

19. Fragment of rock composed of coarse Mica and Quartz. 20. Galena. 21. Galena and Quartz, with a very little Carbonate of Copper.

No. 22. *From three sources of the Umgimvoobo.* Page 14.

Rock-crystal, fresh and subangular.

Dark-coloured and other Agate, abundant; subangular and rolled.

Lydite, subangular.

Hæmatite, subangular.

Green Glass, subangular (water-worn).

Nos. 23 & 24. *From near the source of the Zeitza* ‡. See page 14.

Brown earthy Amygdaloid with Heulandite and Greenearth.

Grey Trap-rock with Agate; freshly broken.

Subangular Agate.

Five pieces of broken unworn Agate.

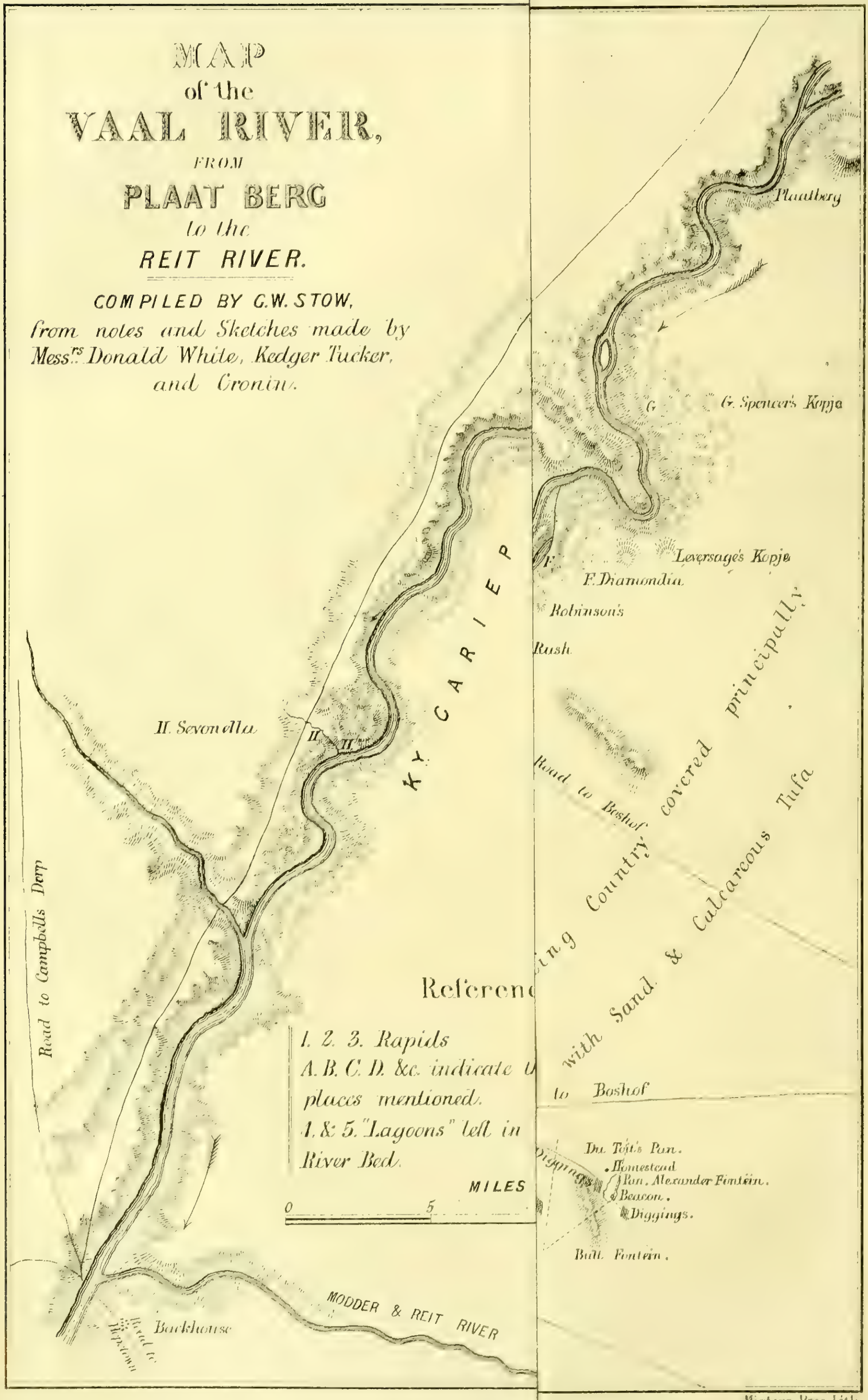
Rock-crystal (from an Agate?).

No. 25. *From near the sources of the T'somo.* Page 14.

Pebble of red and brown riband Jasper, with ancient fracture (glazed).

† Bearing evidence of the presence of metamorphic rocks.

‡ In a letter dated Oct. 10, 1871, Mr. Stow informs me that he has obtained more specimens from this river, like those of the Vaal gravel, and that he is informed of some small diamonds having been found on the Zeitza, S.E. of the Draakensberg.



Mintern Bros. Lith.

Pebble of peculiar Agate-breccia, with ancient fracture.
Subangular Agate, various; and fresh fragments of Agate.
Subangular piece of Magnetite.

No. 26. *From the T'somo, No. 2.* Page 14.
Coarse grey Quartz-grit, weathering brownish, with disseminated Mundic (small cubes). Hard coarse Clay-schist, with disseminated Mundic. Small fragment of calcareous veinstone with Copper-pyrites; small fragment of quartz-vein with Copper-pyrites; a morsel of quartz-vein with Iron-pyrites; and a small piece of fine-grained Galena.

No. 27. *From the T'somo, No. 1.* Page 14.
Hæmatite with quartz.

EXPLANATION OF PLATE I.

Map of the Vaal River from Plaat Berg to the Reit River.

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3. *On the* Geology *of the* Diamond-Fields *of* South Africa. By Dr. John Shaw, Colesberg, Cape Colony.

(Communicated by Dr. Hooker, C.B., F.R.S., F.G.S.)

[Abridged.]

We have presented in the various parts worked for diamonds up to the present date two apparently different classes of soil in which diamonds are found imbedded. The one class exists along the Vaal River and its tributaries, the Reit and Hart Rivers; and the other occurs in the Orange-River Republic, in isolated spots, generally circumscribed, and in many cases in what are called "Pans," which are basin-like hollows, in wet seasons more or less filled with water of a saline character, in dry seasons presenting a whitish surface saturated with salts.

I shall endeavour to show that there is really no distinction in the geological origin of the two classes. It will be convenient, however, in the first place to treat them separately, for the sake of clearness.

The prevailing rocks of the Vaal region and the isolated diamond-farms are *trappean*—greenstone and basalt. There is every indication that the upheaval of these has been continued throughout a vast length of time, and has extended until recently, geologically speaking. The summits of the hills consist of trap, which has been protruded through vast layers of sedimentary strata—generally calcareous sandstones, clay-slate, and such like rocks, all remarkably barren of fossils. Very little disturbance is shown in the lie of these sedimentary rocks. Hence the prevailing character of the ranges is tabular, though dome-like, conical, and even pointed peaks are seen. They are dispersed more or less circularly around dreary flats, which are in many instances of considerable extent. The trap,

MAP of the VAAL RIVER, FROM PLAAT BERG to the REIT RIVER.
COMPILED BY G.W. STOW, from notes and Sketches made by Messrs. Donald White, Kedger Tucker, and Cronin.
References.
1. 2. 3. Rapids
A. B. C. D. &c. indicate the localities of the places mentioned.
4. & 5. "Lagoons" left in the ancient River Bed.
MILES
0 5 10 15
I. Likatelong or Jantje's Town
K. Moonlight or Sloane's Rush
Plaatberg
G. Spencer's Kopje
Leversage's Kopje
F. Diamondia
Robinson's
Fool's Rush
E. Hebron
New Hebron
Sand Drift
Old Drift
A. Kisi Kumma
Union Kopje
New Rush
Blue Jacket
B. Beacon
C. Cawoods Hope
Natal Kopje
D. Gong Gong
H. Sevonella
KY GARIEP
OR
VAAL RIVER
Grass — Sage-tree & Wacht — en — beitjie Sand with Patches of Boulder
Undulating Country covered principally with Sand & Calcareous Tufa
Bad Hope or Victoria
Webster's Kopje
Kevy's Kopje
Good Hope
Colesberg Kopje
Klip Drift
Pniel Kopje
Pniel Mission Station
Road to Boshof
Road to Boshof
Road to Fauresmith
Road to Jacobsdal
Road to Hopetown
Old Road used by Traders
Road to Campbells Dorp
Road to Hopetown
Buckhouse
MODDER & REIT RIVER
De Beer's Diggings
Du Toit's Pan.
Homestead
Pan. Alexander Fontein.
Beacon.
Diggings.
Bult Fontein.
WNW
ESE

intruded laterally, and between previously existing strata, has received their impress, and is now the great conservator of the country from the tremendous denudation going on in South Africa, with its excessively dry climate, its intense heat, and its occasional heavy floods.

The Vaal-River Diamantiferous Region is known to extend from near the town of Potchefstrôm, the capital of the Transvaal Republic, down the whole course of the Vaal to its junction with the Orange River, and thence along the Orange River for at least 60 miles. Digging-operations are at present confined to the Middle Vaal, from the residence of the Griqua Chief, Barend Bloem, at Hebron, downwards on both banks of the river to the Bechuana Kraal of Sibonell. Along the whole course of the Vaal there is the same general development of trap, consisting of basalt, amygdaloids, trap-porphyry, trap-conglomerates, and associated metamorphic rocks. Granite exists nowhere *in situ*; but granite nodules occur in the trap conglomerate. Syenitic greenstone is developed in one of the localities near Klip drift, and seems to be the foundation rock there.

Sedimentary rocks, sandstones, limestones, &c. occur in some of the *Kopjes* (hills or heights) capped by basalt.

The soil on the summits of the rocky hillocks consists of a ferruginous loam and imbedded water-worn pebbles. These pebbles and the loose boulders exhibit the appearance of having been water-worn for a considerable time. They are mainly of basalt, amygdaloid, sandstone, agate, peridot, garnet, tourmaline, quartz, jasper of various colours, granite, binary granite, serpentine, malachite, gneiss, &c.

It is to be noted that the alluvial soil prevails everywhere on the tops of the rocky hillocks, considerably above the present river-bed, and extends inland from the river for two and three miles, and in some cases much further. The hollows are filled with drift sand; and underneath, the pebbly mass is imbedded in a stiff clay, which is most difficult to work by the ordinary washing processes carried on by the diggers, and accordingly has been neglected for the easily washed material of the sides and summits of the heights. The summits are in greater favour than the sides amongst the diggers; and no doubt the wealth of the sides has found its way into the hollows and probably into the gravelly bed of the present river-course.

The history of one digging-centre in the Vaal, Cawood's Rush, supports this opinion. This spot is a low-lying gravelly bank; and the river sweeps round the greater part of it, so as to form it into a species of peninsula. The old watercourse was undoubtedly across the isthmus, where large and very ancient trees still live, indicating the former bank of the river to have been there. The trees around the present bank are all young. When, therefore, it is understood that these trees only occur flanking streams, it is manifest that the peninsula of Cawood's Hope was formerly an island, and that at a very recent period it was the river-bed. It proved a place of unexampled success in the diamond-findings of South Africa. Shells of the genera *Anodon* and *Cyclas*, which live in the Vaal, were dug up in every part of the spot with the epidermis still on. The gravel-was not deep, and the whole Rush was soon dug out. These two facts give additional proofs in favour of the recentness of the deposits; and consequently strong promise that the present river-bed may prove equally rich. The river Vaal is not a rapid stream. It flows sluggishly from one terrace to another, and falls in its course by a series of rapids at intervals of some miles. It winds about to a considerable extent throughout its entire progress. This is in favour of the view that the alluvial gravel has been deposited by the Vaal, as the country is one which the slightest elevation at particular points would alter so as to change the course of the stream for miles. The rapids are caused by basaltic dykes, which may be considered to be kopjes in the process of formation for a future time. Such dykes, moreover, are meanwhile "bars," and prevent the greater part of the material washed down from going beyond them.

The Isolated Diamond-fields are very different in soil from that of the Vaal River. The surface, instead of being a ferruginous loam, is in most cases calcareous. The pebbles are by no means many, and they are all angular and not water-worn.

I have visited the various isolated digging-spots. They are in geological and diamantiferous indications the same. The pebbly mass of the Vaal-River diggings glistens with beautiful agates and crystals of nearly every colour; but the soil washed and sifted in the isolated diamond-fields is not by any means so attractive. The pebbles are fewer, occasional agates, crystals, abundance of tourmaline and garnet amid a mass of fragments of basalt and pieces of serpentine, all imbedded in a more or less calcareous soil, which glistens with talc and mica.

I had been, from the commencement of my study of the diamantiferous tracts of South Africa, on the look-out for the primary and metamorphic series.

I have mentioned the existence of granite in the trap-conglomerate of the Vaal; and I got hold of a water-worn fragment of gneiss, which also occurs in the same conglomerate, as I afterwards discovered. I found, however, no decided traces of true metamorphic rocks till I examined the diamantiferous pans and isolated places. I collected in the course of one tour specimens of gneiss, chloritic schist, mica-schist, and talcose slate in different digging-spots. I found none of these rocks *in situ*; and they no longer exist in connexion with the rock-system of the region, as far as I have been able to ascertain.

It is necessary, before going any further, to enlarge on the nature of these pans, the detritus drifted to which from surrounding tracts is now being searched for diamonds, and is found to contain fragments of the schistose series.

Du Toit's Pan is the most celebrated of all the diamantiferous pans, and may be taken as a type of the pans of the region.

I cannot indorse the views of Mr. Wyley in regard to the origin of the salts of these pans—that the saltness has been left to them by the sea, which at some period (he thinks comparatively recent) swept over the whole, or nearly the whole, of South Africa. With reference to his opinion that the land has been gradually elevated above the sea, I think no one who studies even the botany of the Cape can have doubts that the flora, as a whole, is that of an insular region, and points to a time when South Africa was an island or, it might be, an archipelago.

However much the following paragraph may apply to some parts of the Cape near the coast, it cannot certainly apply to the upland and inner regions which have come under my own observation. He remarks*:—"It will therefore follow that, at a comparatively recent geological period, the greater portion of South Africa was beneath the waters of the sea—that during that time the sandy drift which forms the soil of most of our plains and valleys was deposited, and, when the country was gradually elevated above the waters, a portion of salt was still retained by what had been the old sea-bottom, while in many instances the sea-water remaining in hollows would give rise by evaporation to those larger salt-deposits we frequently meet."

Without attempting any thing like a thorough refutation, it does seem extraordinary to hear of "sandy drifts" and a "soil" deposited by the sea, when the work of ordinary disintegration, weathering, and washing by rain going on at present is so rapid as to deposit in most tracts new soils in our plains and flats in the course of a few generations. The absence of evidences of sea-life, as traces of marine shells &c., in the sands and soil, if so deposited, is altogether inexplicable, since in other such deposits, as in the great European plain of Russia and Prussia, there are abundant evidences of this kind. The present deposits on the surface and to a considerable depth have no connexion, I think, with the period of submergence; and we must look for their origin and that of the salt of the salt-pans to subsequent times, and to causes at present in operation.

We have a *vera causa* in the present localization and isolation of these pans. They receive the drainage of the surrounding heights; and none of it passes away except what may percolate through the lower strata. The various salts from the rocks (sandstones, argillaceous limestones, &c.), but chiefly from the trappean greenstones, settle in the pans, and are held in solution by their waters. They are therefore but a particular example in the general induction that all bodies of water into which rivers flow and from which no waters pass out are salt. They obtain their salt as the ultimate receptacles of the land-drainage around them. All the constituents necessary for the saturation with salts of such waters are to be found in the metamorphic schists &c. to be collected in fragments in the pans.

The formation of these pans is most instructive. Deep wells have been sunk on the upper part of the slopes of Du Toit's Pan. One of these must be considerably over 30 feet deep. The dip of the strata is here seen to advantage, and is about 30° towards the pan. This inclination is caused by the elevation of a greenstone porphyry from beneath, forming a more or less regular ring around the pan, where marginal strata have thus come to be raised. General denuding pro-

* 'Report on the Geology of South Namaqualand,' p. 37.

cesses have in time, no doubt, aided in enlarging it; and its waters, having been confined and imprisoned, have become salt, from being at first after the upheaval brackish. This, I feel convinced, is its history in a few words.

But, in addition, gradual wearing of the tilted strata would give a base-soil of the constituents of the rocks, which are mainly siliceous and calcareous; hence the calcareous tufa and calcareous soils so abundant everywhere, and conspicuously so in the pans. The hardness of this substance merits for it the name of rock; but it is deposited in the same way as an ordinary earth. It is afterwards kept compact by its avidity for moisture, which it receives from the occasional rains. When broken up and dried by exposure, it becomes quite friable, and moulders into loose powdery masses.

The *kalk* (as the calcareous tufa is popularly called) of Du Toit's Pan does not, however, appear to be very siliceous, and, on this account, is not so consolidated and hardened as in many other parts of the country, especially along the Lower Vaal, where the silex of the amygdaloid is chemically combined with the calcareous sediment from the same and other rocks.

The question of Diamantiferous indications is one of some importance. From the beginning of the digging, garnet and tourmaline have been regarded as associates of the diamond. These prevail along the Vaal and in the isolated fields in all good diamantiferous soil. In Du Toit's Pan a peculiar substance is favoured by the diggers, consisting of a fine clayey detritus, glistening with talc, and abounding in garnets, tourmaline, and corundum. It is of a greenish colour, but presents occasionally the appearance of burnt brick when impregnated with iron. It is called, from its resemblance to bran, "semmels." This I have considered the correlative of itacolumite—a substance I have failed to discover in any of the "rushes."

These diamantiferous indications apply throughout the whole of the diamond-producing region. Even the talcose detritus of Du Toit's Pan occurs with varying characters in occasional patches of the Vaal-River diggings. At Pniel, where mining to some depth was carried on, it occurs close to the fundamental rock—greenstone. I am therefore disposed to think that the talcose slate, which produced the detritus, was the original matrix of the diamond, and that this rock was one of the series of metamorphic rocks—gneiss, mica-schist, &c. In the diamantiferous pans traces of these have been preserved, chiefly from their isolation and from being undisturbed, as the tract along the Vaal River has been. But the inference is that the original diamantiferous rock has extended throughout the whole region of that part of South Africa. This and the associated rocks were disturbed by the greenstone upheavals. It is likely that these upheavals occurred at various times. During and subsequent to these disturbances was the great lake-period of South Africa, when the immense deposits of lacustrine formations were made. The ancient rocks yielded to denudation and wearing, in some cases went towards the formation of trap-conglomerates, and generally have found their way to the nuclei of the present period, the Vaal valley and those of its tributaries, the Reit and the Hart, and the pans and sheltered spots where isolated diamantiferous farms exist.

It is difficult to give an exact chronology of the changes; and I am still engaged in the study of that part of the subject. I am satisfied, however, from what I have now advanced, that the following points may be regarded as demonstrated:—

1. The diamonds originally belonged to one of the members of an ancient metamorphic series, and probably to a talcose slate.

2. That these rocks occupied the heights during a later period of trappean upheaval.

3. That a period of lakes prevailed during and after this trappean upheaval; and that we have the last traces of these in the pans of the region, many of which have become dry, filled up, and many more are now extinct.

4. The Vaal River may have possibly connected a chain of these lakes.

5. The processes of denudation have caused the ancient rocks to vanish, the greenstone to reveal itself in all directions, and the detritus and débris have found their way into the centres of drainage—the Vaal River and its tributaries and the isolated spots and pans of the Orange-River Republic.

6. It is undoubtedly the case that some of the diamantiferous soil is recent as a deposit in its present position. This is accounted for by the great amount of surface-drainage and carrying in connexion with South-African floods. The soil is continually being changed from one place to another. A surface-flow of water, bearing mud, stones, &c. along with it, accompanies every thunderstorm. The soil associated with the diamond in the pans at considerable depth is purely the *detritus* of talcose slate or clayey limestone, and cannot be recent, and was probably deposited in the lake-period; accordingly the date of the first dispersion of the diamond from the original matrix is of considerable antiquity; but during the lake-period and subsequently it has been going on.

7. It would be very foolhardy in any one to say that no great amount of the diamantiferous soil has been carried down by the Vaal to the Orange River. Possibly the absence of minute diamonds along the Vaal diamond-field is to be explained by the river having carried them downwards. There is, however, every reason to believe that the same diamantiferous soil occurs along the Orange River. Diamonds have been found on both sides of that river. We know less, meanwhile, of the course of the Orange River and the territory directly to the north and south of it than we do of the interior of Africa.

Discussion.

Mr. Woodward mentioned that Mr. Griesbach and M. Hübner had been over the country described in these papers, and had communicated a map of it to Petermann's Journal.

Mr. Griesbach stated that the rock described as metamorphic in the paper was by M. Hübner regarded as melaphyre, and that in some parts of the Vaal valley the beds of the Karoo formation might be seen *in situ*. He disputed the possibility of any of the gravels being of glacial origin. He was convinced that there were no metamorphic rocks on the western side of the Draakensberg; those regarded as such probably belonged to the Karoo formation.

Prof. Tennant commented on the large size of the diamonds from the Cape, of which he had within the last few months seen at least 10,000, many of them from 30 to 90 carats each. Some broken specimens must, when perfect, have been as large as the Koh-i-Noor.

Mr. Tobin corroborated the information given by Mr. Stow, and stated that the source of the Vaal was in sandstone, and that it was not until it had traversed some distance that agates, peridot, and spinel were met with. The large diamonds, in his opinion, occurred principally in old high-level gravels, at a considerable elevation above the river, which had much deepened its valley since the time of their deposit. At Du Toit's Pan, however, none of the diamonds, nor, indeed, any of the other stones, showed any signs of wear; and he considered that at that spot was one of the centres at which diamonds had been found in their original matrix.

Mr. Daintree stated that in Australia there were agate-bearing beds of amygdaloid greenstone, similar to those in South Africa, and that he had called attention to their existence in the neighbourhood of the Burnett river, where since then a diamond of the value of £80 had been discovered.

Prof. Maskelyne commented on the dissimilarity of the minerals found in the diamond-bearing beds of Brazil from those of Du Toit's Pan or of South Africa generally. He thought that possibly the mineral described as peridot might be bronzite, which, however, came from igneous rocks; and the remarkable fact was that with this and garnet occurred unrolled natrolite, and diamonds in an equally unrolled condition—which was suggestive of their having been due to a common origin.

Mr. Ward gave an account of an examination of some of the rock from Du Toit's Pan, with the view of discovering microscopic diamonds, none of which, however, had been found.

Prof. Rupert Jones had been equally unsuccessful in the search for minute diamonds, both in sand from Du Toit's Pan and in ochreous gravel from Klip drift. He pointed out the waterworn condition of the agates from Du Toit's Pan, which showed aqueous action, though there were also several other minerals present in a perfectly fresh and unrolled condition. He thought a careful examination of the constituent parts of the gravel might ultimately throw light on their origin. That fluviatile action was sufficient to account for their presence had already been shown by Dr. Rubidge and others, who had treated of the grand plateaux and denudations of the district under notice.

November 22, 1871.

Samuel Baillie Coxon, Esq., of Usworth Hall, Durham, was elected a Fellow of the Society.

The following communications were read:—

1. Notes *on some* Fossils *from the* Devonian Rocks *of the* Witzenberg Flats, Cape Colony. By Professor T. Rupert Jones, F.G.S.

Through the courtesy of Mr. G. S. Hayward, of Edmonton, and Mr. Rudler, of the Geological-Survey Museum, I have had the opportunity of examining some fossils from the Tulbagh Division, Cape Colony, and wish now to point out the interest they have for South-African geologists.

They were sent to England by Mr Thomas Hayward, of Witzenberg, and were found, some on the surface, and some in the shafts made in the search for coal and other minerals on the Witzenberg Flats, in the south-western part of the Tulbagh Division, on two farms belonging to Mr. Louw, who, I am informed, has gone to considerable expense in his endeavours to develope the resources of the Colony.

The above-mentioned flats constitute a valley, sharply elliptical in outline, between the Witzenbergen on the west and the Schurftebergen on the east. It is about 6000 Cape roods long from north to south, and about 1500 broad across the middle. The shafts were made on the Flakte farm, at the foot of the Schurftebergen, at about 300 Cape roods from the Government boundary-line along these hills. In one shaft, at 35 feet depth, were found hard and soft, earthy, purplish strata, with clay bands, and a hard, mottly-grey schist, full of casts of Encrinital joints and stems.

In the other shaft, at 50 feet, was soft dark-grey mudstone, with obscure casts of *Orthis palmata* and Trilobites; and at 50 to 67 feet similar rock, with casts of *Phacops africanus**, *Homalonotus Herschelii*, and *Spirifer antarcticus*, also nodular and disseminated iron-pyrites. At 70 feet the same mudstone contains casts of *Orthis palmata*. At 72 feet (in the tunnel) the mudstone contains casts of *Spirifer Orbignii* and *Orthis palmata*, and is associated with fine-grained ferruginous sandstone that has on one of its bed-planes oblique and vertical projections, of concretionary origin, that bear stratification-lines parallel with the sandstone. Nodular pyrites, with lines of the stratification of the sandstone in which it was concreted, came from the tunnel, at 35 feet from the shaft.

The fossils of this sandy shale, or mudstone, prove the existence of the Bokkeveld or Devonian formation west of the Gydow Pass and north of Mitchell's Pass, as indicated by Mr. Andrew Wyley, Dr. Rubidge, and Dr. Hochstetter, and strengthen Dr. Rubidge's

* For the account of these Devonian fossils of Cape Colony see Messrs. Sharpe and Salter's Memoir in the Trans. Geol. Soc. 2nd Series, vol. vii. pp. 203 *et seq.*

suggestion that the great schistose formation of the Cape Colony is of Devonian age.

Mr. Wyley makes the Witzenberg Flats a synclinal basin of the "Table-Mountain Sandstone," *underlying* Devonian schists ('Notes of a Journey in two directions across the Colony,' &c., folio, Cape Town, 1859, p. 3). But the sections given by Bain*, Rubidge†, and Hochstetter‡ disprove the existence of such a syncline. The basement schists, regarded by Bain as of Silurian age, have been already assigned on stratigraphical grounds to the Bokkeveld series by Rubidge and Hochstetter.

A further point of interest in the Tulbagh district is the occurrence of coal, referred to by Mr. C. L. Griesbach (Geol. Soc. Quart. Journ. 1871, No. 106, p. 57). As far as the Witzenberg Valley is concerned, we learn from a Cape Newspaper of November 4, 1869, that the following section was obtained in a shaft made in search of coal at Geelboschrug, on the flats between the Witzenberg and the Schurfteberg:—

"Alluvium, 1 foot; yellowish clay, 2 feet; ironstone and quartz, with some lead and copper, 8 in.; white clay, 12 in.; iron bank, 4 in.; white clay, 5 ft.; iron bank, 1 in.; white clay, 12 in.; ironstone, 4 in.; white clay, 24 in.; iron bank, 5 in.; red clay (zoza), 30 in.; brownish clay, with sulphur, 6 in.; iron lode (red), 6 in.; iron deposit, yellow and black, 8 in.; yellow clay with ironstone, 6 in.; coloured clay, 12 in.; iron bank, 4 in.; black clay, with pyrites, sphærosiderite, and red ironstone in lumps and plateaux, 10 feet opened." (=30 feet).

At 50 feet "highly carbonized wood" was stated to have been found. The beds were said to have a dip of 45° to the west.

This section fills the hiatus in the upper part of Mr. Hayward's section above given. These beds cannot represent the true Coal-measures; far more probably they are mere alluvial deposits, originating in the wreck of the local "Devonian" strata; but they certainly fill all the space, between the Devonian substrata and the surface, in which coal could be found; and, as the great "Table-Mountain Sandstone" (here denuded) covers the fossiliferous shales in the neighbouring Bokkeveld, we cannot expect that true Coal-measures would be found resting directly on the fossiliferous mudstones of the Witzenberg valley.

Palæozoic coal-measures have been found on the Kowie River§ (Albany), on the other side of the Colony, 450 miles east of Ceres, on the strike of some of these western so-called "Devonian" beds; and possibly the Wittebergen, between Ceres and the Karoo, may contain the old Coal-measures along this line of strike, although neither Bain nor Wyley ‖ was successful in finding them on the

* Trans. Geol. Soc. ser. 2, vol. vii. pl. 21.

† Quart. Journ. Geol. Soc. 1859, vol. xv. p. 196; Geologist, 1862, vol. v. pp. 49, 367.

‡ 'Reise der Novara,' Geol. Abtheil. vol. ii. p. 21.

§ Quart. Journ. Geol. Soc. vol. xxvii. p. 51.

‖ Mr. Wyley regarded the "Karoo Beds" as being the equivalent of the line of section crossing these western districts near Ceres. Nor do they occur near Prince-Albert, on the same strike, about seventy miles to the east, where Dr. Atherstone and Mr. Thomas Bain lately found *Devonian* fossils, close on the trap-breccia of the Karoo, on their traverse northward from Riversdale. At the last-named place, however, in the Swellendam district, and about 50 miles to the south, *Lepidodendron* has been found, both by the above-mentioned explorers and others, either in the Devonian schist forming the country generally, or in some patch of Carboniferous rock.

Some further indications of the geology of the Witzenberg Flats and the Schurftebergen are afforded by Mr. Hayward's specimens. The mountains yield a white and red sandstone traversed by quartz-veins and infiltrated with manganite. This is probably the Table-Mountain Sandstone flanking the eastern side of the valley. Quartz crystals and pebbles of quartz, ironstone, and jasper occur on the mountains and over different parts of Mr. Louw's farms. In Flakte Farm, at the foot of the mountain, coarse friable red sandstone, with black manganese ore, occurs. In Rozendale Farm, in the upper and middle part of the valley, dark mudstone, like that of the shafts, crops out, with *Spirifer Orbignii, Orthoceras vittatum* (Sandberger), and *Homalonotus Herschellii*; and sandstone with casts of *Spirifer antarcticus, Terebratula Bainii, Productus,* and some obscure fossils, occurs; also hard, greenish, trap-rocks, with ferruginous and siliceous geodes, and a curious rock consisting of pebbles of hard bituminous shale in a dark grey trap. Hæmatites and black manganese ores also occur on Rabie and Flakte Farms.

Discussion.

Mr. Godwin-Austen remarked that the presumed Devonian species of South Africa appeared not to have been completely identified with those of European origin. Although, judging from the range of European marine mollusca, some of which were found of precisely the same species both in Europe and at the Cape, there was nothing surprising in the extension of any old deposit, yet it seemed unreasonable to suppose that the whole district over which the widespread Devonian rocks extend could have been submerged at the same time. He traced the original foundation of the Devonian system to the late Mr. Lonsdale, who, in the fossils found in the deposits of Devonshire, thought he traced sufficient grounds for a marked discrimination between those beds and those of Carboniferous age. Mr. Austen, however, had always regarded the Devonian system as merely an older member of the Carboniferous, holding much the same relation to it as the Neocomian to the Cretaceous; and he would be glad to see it recognized, not as an independent system, but merely as the introduction of that far more important

European coal-measures, and the Lower Ecca beds (his "Lower Karoo Shales") as probably equivalent to the "*Carboniferous Shale,*" and the sandstone beneath these to the "Carboniferous Limestone." See his 'Notes of Two Journeys,' &c., p. 61, and Quart. Journ. Geol. Soc. vol. xxiii. p. 172.

system the Carboniferous, during the deposit of both of which the globe presented the same physiographical conditions.

Mr. Etheridge did not agree with Mr. Austen as to the supression of the name of Devonian system, and commented on its widespread distribution, and on the peculiar facies of its fossils, and their importance as a group. He was rather doubtful as to specific determinations arrived at from casts. Though the species of many fossils of Queensland procured by Mr. Daintree did not correspond with those of European areas, yet some of the corals were identical with those of South and North Devon, as were also the lithological characters of the containing beds.

Mr. Seeley objected to any attempt to supersede the arrangement of the South-African rocks in accordance with the local phenomena by correlating them too closely with any European series. The recognition of the correspondence in forms seemed to him more to prove a similarity of conditions of life than any absolute synchronism. As to the connexion between the Devonian and Carboniferous systems, he agreed with Mr. Austen in regarding the one as merely constituting the natural base of the other.

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2. *On the* Geology *of* Fernando Noronha (S. lat. 3° 50′, W. long. 32° 25′). By Alexander Rattray, M.D. (Edin.), Surgeon, R.N.

(Communicated by Prof. Huxley, F.R.S., F.G.S.)

H.M.S. 'Bristol,' Barbadoes, Sept. 9th, 1871.

Although the visit of H.M.S 'Bristol' to Fernando Noronha, situated in the South Atlantic, was limited to one full day, the following notes on the geology of the seldom visited group, of which it forms by far the largest, may be of some interest. So little known are these islands, except to whalers, and the Brazilians, who have converted them into a penal settlement, that the present Admiralty chart, an imperfect one from French authorities, dates as far back as 1735. The chief object of the 'Bristol's' visit was to ascertain the height of the principal peak (one of singular shape) and the nature of the anchorage, &c.*

Fernando Noronha itself is about four miles long, and on an average one mile broad, and consists chiefly of an undulating plateau from 100 to 300 feet above the sea-level, sloping steeply towards sandy beaches and bays, or ending in bold bluffs or cliffs, and rising occasionally into what the inhabitants term "mountains," of which there are four or five, from 500 to 700 feet high. At the eastern end of Noronha lie the remaining islets, five or six in number, chiefly small and almost unused.

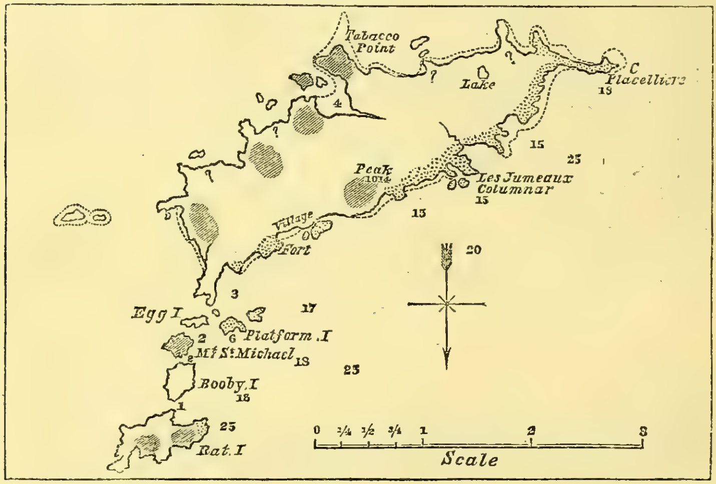
The surface rock of the group appears to consist of a very coarse conglomerate, composed of large rounded basaltic boulders and

* The result of this has been the issue of a new Admiralty chart, dated Jan. 1, 1872.

pebbles, enclosed in a hard dark-red clayey matrix, of which (disintegrated) the abundant and highly fertile soil apparently consists, dry and fissured during the sultry season, but soft, tenacious, and muddy during the heavy rains of the wet season.

Beneath this, and forming the most marked, and apparently the most abundant rock of the island, is a hard, tough, compact, dark, dull-coloured, fine-grained basalt, which at some places, as at Les Jumeaux, is distinctly columnar. Of this rock the most prominent bluffs, cliffs, and off-lying rocks appear to consist (see map and outline, figs. 1 and 2).

Fig. 1.—*Sketch Map of the Geology of Fernando Noronha.*



Basalt.

Granite.

The rest Conglomerate.

The highest peaks of the group evidently consist of a fine-grained light-grey granite, and notably Mount St. Michael, a huge, abrupt, rounded, almost woodless islet, which is altogether granitic—and also Fernando Noronha peak, situated about the centre of the north side of the main island, near the convict village. This is a remarkable, bold, inaccessible, needle-shaped prominence, 1014 feet high, which protrudes through the conglomerate flanking its base.

Large wave-worn masses of granite, and especially basalt, as well as basaltic boulders from disintegrated conglomerate, lie plentifully scattered along the fine yellow sandy beaches, especially at the chief landing-place close to the Fort Rock. Water, not over abundant, muddy and brackish, is only found near the beach.

It is a noteworthy fact that Fernando Noronha is 194 miles to the

N.E. of Cape San Roque, the most eastern part of the South-American continent, the intervening channel being comparatively shallow compared with the deeper waters to the east and north-east. The geology and physical geography of the two, thus contiguous, ought evidently therefore to be studied together. And it would be interesting to know whether these islands, a mere speck in the ocean and their rock-formations, are or are not connected with the enormous mountain-chains and rock-systems of the adjacent mainland—the volcanic rocks of the former with the igneous mass which forms so large a part of Central, Southern, and Eastern Brazil, and especially with the mountain-chains running for hundreds of miles along this coast in a N.E. direction to terminate near Cape San Roque, of which Fernando Noronha may be regarded as a terminal spur. May not the conglomerate of Fernando Noronha be likewise connected in origin and nature with the well-marked tertiary deposits flanking these mountain-chains of Eastern Brazil?

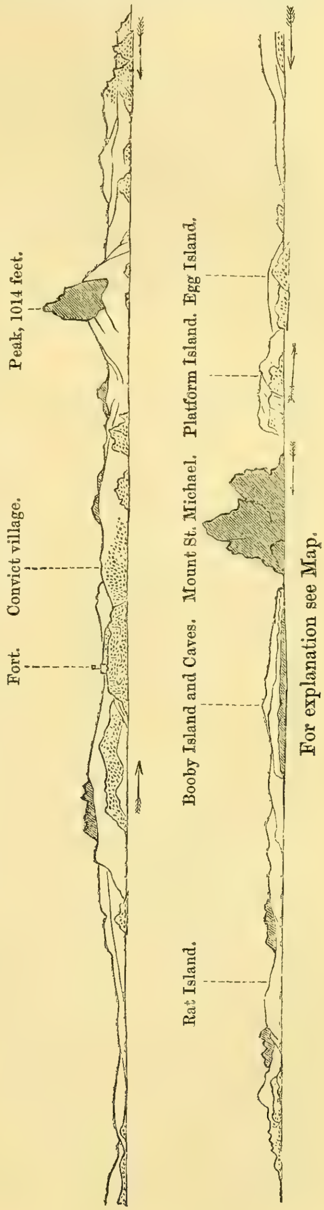


Fig. 2.—*Geological Outline of Fernando Noronha and the neighbouring islets.*

Evidence of a gradual vertical movement in these islands in comparatively recent times is not wanting, thus:—*first*, in the old high-water mark of the group being considerably above its present level, as seen, for example, at the base of the Fort Rock, Le Grange, Les Jumeaux, &c.; and, *second*, in the sides of Booby Island, now hollowed into a long series of caves, whose roofs lie well overhead. The nature of a large perforation in the inner end of Cape Placellière, apparently in basalt, and high above the modern high-water mark, could not, for want of time, be examined. But the above-mentioned appearances cannot have resulted from the wash of rough seas, or "rollers" like those common at Ascension and St. Helena (but unknown here), and were doubtless formed when the islands were deeper in the water.

Darwin believes in a gradual rising of the Brazils, and of the South-American continent in general. Have these corresponding phenomena any connexion? Or are either, or both, related to the reported appearances of volcanic eruptions, even so late as 1836 (as indicated in our most trustworthy maps) in the middle of the Atlantic, some 16° to the N.E. of Fernando Noronha, close to the equator, and midway between the Brazilian and African coasts?

The correlation of the rocks of this group, and the minutiæ of their geology must be left to future investigators.

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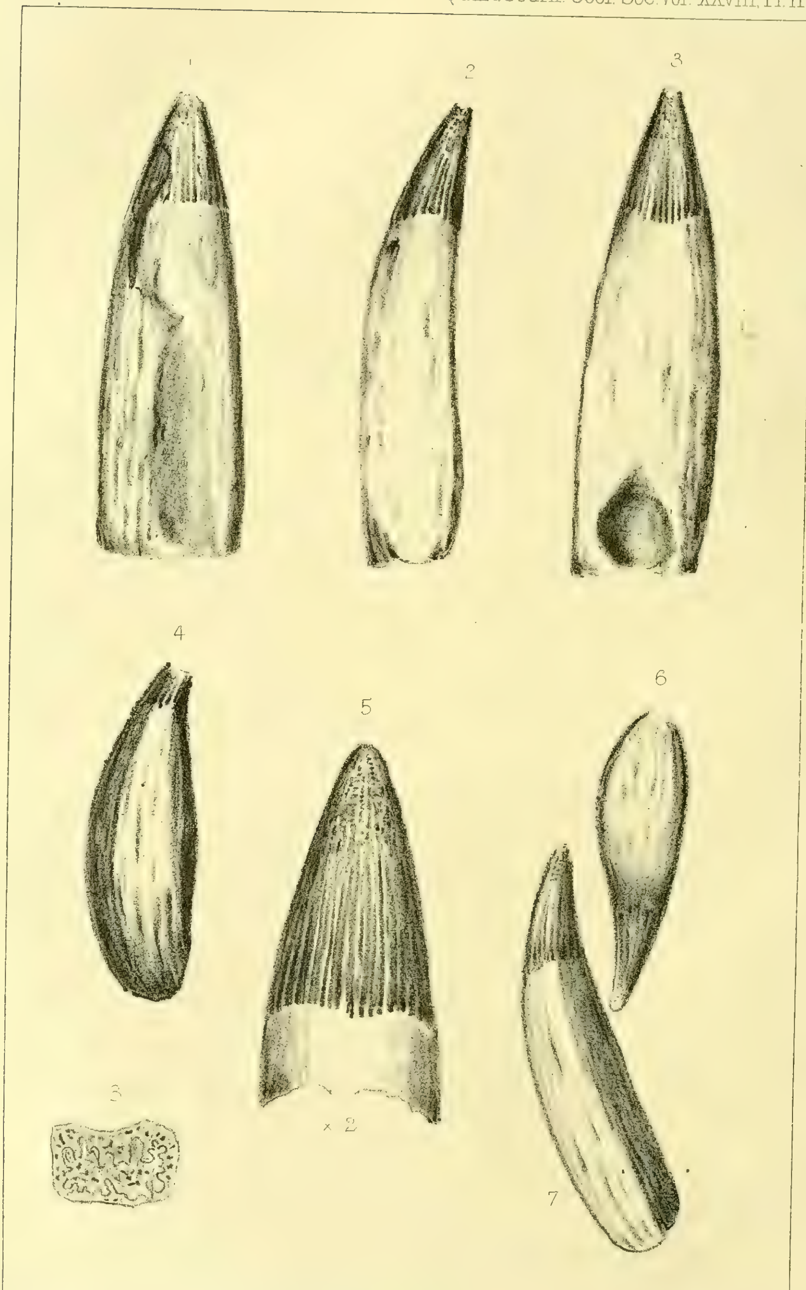
3. *Note on some* Ichthyosaurian Remains *from* Kimmeridge Bay, Dorset. By J. W. Hulke, Esq., F.R.S., F.G.S.

[Plate II.]

These remains consist of several teeth and of fragments of a skull transmitted to me for examination last summer by J. Mansel Pleydell, Esq., F.G.S., to whom I have been already indebted on several occasions for opportunities of bringing under the Society's notice Saurian fossils from the Dorsetshire Kimmeridge beds. Unfortunately, as so commonly happens when the extrication of fossils from the shale is attempted by unskilled labourers, the bones were smashed into so many pieces as to render the restoration of the skull quite impossible. Estimated by the size of the broken pieces, the snout was probably not less than three feet long, and it was proportionately stout. Of the teeth some are shorter, more curved, and relatively stouter than the others. In both forms the crown is bluntly pointed, its base passes evenly into the root without any separating cingulum, and the proximal end of the root is laterally compressed, which gives its cross section an oblong figure (fig. 8), the longer sides of which are parallel with those of the dentary groove. The crown is strongly striated; the striæ diminish regularly from the base to the apex, near which they break up into lines of minute tubercles, which are continued to the very extremity. The most perfect of the longer teeth (only the extreme tip of the crown of which is missing) is $30\frac{1}{6}$ lines (English) long, of which the crown forms $8\frac{1}{6}$ lines (figs. 1–3). The base of its crown has an antero-posterior diameter of $5\frac{1}{2}$ lines nearly, and a rather smaller transverse diameter. At the middle of the root these diameters are $8\frac{1}{2}$ lines and 6 lines nearly, while those of the proximal end are slightly less. The inner surface of this part of the root has in several of the teeth been hollowed by an advancing germ (fig. 3). The entire length of a perfect tooth of the shorter form (figs. 4 & 6) is 20 lines; but some of the broken ones were slightly longer. The crown of this tooth is $5\frac{1}{2}$ lines long; and the



J. W. Hulke Del.

Maclure & Macdonald imp

TEETH OF ICHTHYOSAURUS FROM KIMMERIDGE

maximum antero-posterior diameter of its root (nearly at the middle) is about 8 lines. The inner longitudinal line of this tooth is less incurved than the outer one.

Their much larger size at once separates the teeth of this Kimmeridge species from those of the slender-snouted Liassic species (*I. longirostris, I. tenuirostris, I. acutirostris*), and from those of the Kimmeridge *I. enthekiodon*, which I described last session*. From the teeth of *I. communis* they differ notably in the relatively greater ventricosity of the root of the latter. From the strongly fluted tooth-root of this species, as also from the similarly marked tooth-root of *I. intermedius* and of *I. lonchiodon*, the tooth-root of this large Kimmeridge species is easily distinguishable by the comparative faintness of its linear furrowing. The crown is much stouter than that of *I. lonchiodon*, and its striation makes it impossible to mistake these teeth for those of *I. platyodon*. They bear a close general resemblance to the teeth of *I. campylodon*; but, from a comparison of them with a good series of *campylodon* teeth in the British Museum, I find they differ from these in the proportions of the root and crown, which latter is longer and less stout in the Kimmeridge species; but they are better distinguished by the prolongation of the striæ in the form of lines of minute tubercles to the extreme end of the crown, which in *I. campylodon* is smooth, the sculpturing ceasing at a short distance from its apex.

EXPLANATION OF PLATE II.

Ichthyosaurian Teeth from Kimmeridge.

Figs. 1, 2, 3. One of the longer teeth, natural size: 1, outer surface; 2, side; 3, inner surface with germ-hollow.
,, 4. Root and small piece of the crown of one of the lesser teeth.
,, 5. An unworn crown, × 2, to show the sculpturing.
,, 6, 7. A lesser and a longer tooth as bedded in matrix.
,, 8. Transverse section of the root of one of the longer teeth near the base.

Discussion.

Mr. Seeley did not consider that, in the main, the teeth of reptilia afforded any criteria for specific determination. In the Cambridge Greensand, though there were five species of *Ichthyosaurus*, possibly including a second genus, the teeth found were so closely similar that it would have been impossible, from them only, to identify more than one species.

Mr. Boyd Dawkins recognized in the specimens exhibited by Mr. Hulke a form of tooth he had found in the Kimmeridge beds of Shotover, near Oxford, but which he had been hitherto unable to attribute to any recognized species. He could not fully agree with Mr. Seeley as to the absence of specific criteria in the teeth of Saurians, as, from his own experience, he was inclined to attribute some importance to their external sculpturing.

* Quart. Journ. Geol. Soc. vol. xxvii. p. 440.

4. Appendix *to a* "Note *on a new and undescribed* Wealden Vertebra," *read 9th February* 1870, *and published in the Quarterly Journal for August in the same year**. By J. W. Hulke, Esq., F.R.S., F.G.S.

On the 9th of February, 1870, I brought under the Society's notice the neural arch of a huge Wealden vertebra which in the preceding summer I had obtained at Brooke, on the south coast of the Isle of Wight. As it was quite unlike any known form, I referred it to a provisional genus *Eucamerotus*. From certain peculiarities of its internal structure I strongly suspected that when evidence of the form of its missing centrum should be obtained, it would be found to resemble a Mantellian Streptospondylian centrum in the British Museum, labelled "No. 28632. Wealden, S. E. England." And in a foot-note to my paper, I wrote "should their identity be hereafter established, there will still be the further question, What is this *Streptospondylus*?"

During the past summer my suspicion has been verified, and the question concerning this *Streptospondylus* is also solved. I find that my *Eucamerotus*, *Ornithopsis*, Seeley, probably *Streptospondylus Cuvieri*, Owen, and the huge *Cetiosaurus*, Owen, whose recently restored remains strike the visitor to the Oxford Geological Museum with amazement, are all members of one genus (the first two are probably one species) characterized by opisthocœlian trunk-vertebræ, having an unusually complex and very highly developed neural arch, but more particularly marked by a large and deep excavation in the side of the centrum beneath the root of the neurapophysis†. I have learned from Prof. Phillips that this *Cetiosaurus* furnished the moterials out of which Prof. Owen constructed his genus; it claims, therefore to be its type. Should this be accepted as the type of the genus, then *C. brevis*, Owen, a S. E. England and Wealden form, must, I suppose, find another place, since the trunk-vertebræ assigned to it in the "Report on British Fossil Reptiles" are described as having both articular surfacs concave.

Discussion.

Mr. Boyd Dawkins, who had recently visited Oxford, stated that he had there examined the remains referred to. There was, however, no tooth found with them sufficiently perfect to show the nature of the food on which the animal subsisted. But one of his students had lately found, in the same pit that had afforded the remains, a tooth corresponding with a stump of a Cetiosaurian tooth in the Oxford Museum; and the perfect crown agreed in its principal characters with that of *Iguanodon*, with which, therefore, the *Cetiosaurus* seemed to be allied. It was probably a vegetable feeder. Mr. J. Parker had lately procured from the Oxford Clay a number of saurian remains; and among them were some vertebræ of *Megalo-*

* Vol. xxvi. p. 318.

† This at once separates them from the vertebræ of *Streptospondylus major*, Owen, another Wealden form.

saurus, to which were articulated others presenting distinctly the characters of *Streptospondylus*. He thought that most of the Streptospondylian vertebræ might prove to belong to the cervical region of Dinosaurians.

Mr. SEELEY disputed the attribution to *Cetiosaurus* of the vertebræ described, and questioned whether the remains at Oxford might not be assigned to *Streptospondylus* or *Ornithopsis*. The depressions in the vertebræ, which might be connected with the extension of the air-cells of the lungs, did not exist in *Cetiosaurus*, but were to be found in *Megalosaurus*. As to the tooth mentioned by Mr. Dawkins, he was uncertain whether it should be referred to what he considered *Cetiosaurus* proper or to the Oxford reptile.

Mr. HULKE replied, pointing out that, since the determination of the Oxford reptile as *Cetiosaurus*, numerous other remains of the same species had been discovered which had added materially to the basis of classification.

DECEMBER 6, 1871.

John Richard Burton, Esq., B.A. (Lond.), Head Master of Bewdley Grammar School; the Rev. J. Cater, March, Cambridgeshire; Richard Daintree, Esq., Government Geologist of Queensland; John Davies Enys, Esq., of Trilissick, Canterbury, New Zealand; Henry George Bonavia Hunt, Esq., 4 Garden Court, Temple, E.C.; Capt. Alexander Hadden Hutchinson, R.A., South Camp, Aldershott; Joseph Coventry I'Anson, Esq., Darlington; James T. B. Ives, Esq., 30 Weymouth Street, Portland Place, W.; Albert George Kitching, Esq., Enfield; Leonard Lyell, Esq., 42 Regent's Park Road, N.W.; John Earl Hunter Peyton, Esq., F.R.A.S., 108 Marina, St. Leonard's-on-Sea; Sydney B. J. Skertchly, Esq., of the Geological Survey of England and Wales, 13 Clonbrock Road, Stoke Newington, N.; and Henry Walker, Esq., 100 Fleet Street, E.C., were elected Fellows, and Prof. Giovanni Capellini, of Bologna, a Foreign Correspondent of the Society.

The PRESIDENT announced the bequest to the Geological Society, on the part of the late Sir Roderick Murchison, of the sum of £1000, to be invested in the name of the Society or of its Trustees, under the title of the "Murchison Geological Fund," and its proceeds to be annually devoted by the Council to the encouragement or assistance of geological investigations. The donation of the proceeds of the Fund was directed by the Testator to be accompanied by a bronze copy of the Murchison Medal.

The SECRETARY, Mr. Evans, having read the extracts from the Will of the late Sir Roderick Murchison relating to this bequest,

Sir PHILIP EGERTON proposed the following resolution:—"That this Meeting, having heard the announcement of the bequest made to the Geological Society by the late Sir Roderick Murchison, desire to record their deep sense of the loss the Society has sustained by his death, and their grateful appreciation of the liberal bequest for the advancement of geological knowledge placed at their disposal by their late distinguished Fellow.

Mr. J. Gwyn Jeffreys seconded this proposition, which was carried unanimously.

The following communications were read:—

1. *On the* presence *of a* Raised Beach *on* Portsdown Hill, *near* Portsmouth, *and on the* occurrence *of a* Flint Implement *on a high level at* Downton. By Joseph Prestwich, Esq., F.R.S. &c., President.

A few years ago* I traced the well-known old beach of Brighton past Arundel to Chichester and Bourne Common—a distance of 42 miles. At Brighton it is only from 8 to 12 feet above the level of the present beach; near Arundel it attains a height of 100 feet, near Chichester possibly of 130 feet, and at Bourne Common of 140 feet. Westward of this point it had been found on the east coast of the Isle of Wight; but I failed to detect it at any point inland, or at any considerable elevation.

I now beg to call attention to an interesting section which I have more recently observed at a spot 10 miles westward of Bourne Common, and 5 miles inland. It is a mile and a half E.N.E. from Fareham, on the right-hand side of the lane leading from East Cams to Nelson's Monument, which stands on the western extremity of Portsdown Hill. This hill, as is well known, is a bare narrow chalk ridge, running 6 miles from east to west, and rising in the midst of a lower surrounding Tertiary area to a height of from 300 to 400 feet. The subangular flint-gravel of Chichester, Havant, and Portmouth ranges up to the southern foot of the hill, to a height of about 40 feet above the sea-level. It may be seen in a pit by the side of the railway half a mile west of Porchester station.

Above this lower level the slope of the hill here consists of bare chalk, with the exception of this one spot, on the north side of East Cams Wood. Although the pit is close by the road, it is not readily seen. It is situated at a height of 125 feet above the sea, or of 85 feet above the ochreous flint-gravel at its base—whence the latter stretches westward, forming the great plains of gravel extending past Havant and Southampton to Poole, which have been so well described by Mr. Codrington †.

The pit is a shallow arc, and presents the following section:—

a. Grey earth and sand, with angular and rolled flints, 0 to 2 feet.
b. Light-coloured laminated sands, with seams of shingle, } 4 to 6 feet.
c. Light-coloured coarse flint-shingle, with a few whole flints, }
d. Chalk rubble, patches of.

The beds *b* and *c* constitute a true shore-shingle, composed of rolled and imperfectly rounded flints, imbedded in a matrix of light-coloured sand and loam, very different from the ochreous subangular

* Quart. Journ. Geol. Soc. 1859, vol. xv. p. 215.
† Ibid. 1870, vol. xxvi. p. 528.

flint-gravel at the base of the hill. In the shingle are a few Tertiary flint-pebbles, and not a few large unworn flints, with a number of sharp angular flint fragments. The only foreign material I found was a fragment of reddish quartzite. I saw no organic remains of any description. But the pit requires further search, especially as the workmen were not present on the occasion of my visit.

I found, however, in bed *a* a rude flint implement; but whether derived from the surface or peculiar to bed *a*, I could not positively say. It was at a depth of 1½ foot from the surface. Its type is not sufficiently distinctive to indicate its age.

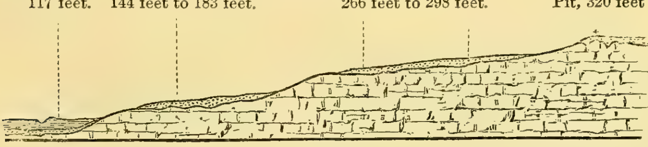
I have not yet succeeded in tracing this old shingle-beach further westward, where it is desirable to determine its exact position in relation to the several gravels of the South-Hampshire area.

There can be no mistake made about the character of the shingle. It is not so rounded as the Tertiary flint-pebbles, which can be readily distinguished amongst it, while it is far more worn than the subangular gravel at the base of the hill. In places there are signs of disturbance as though from the effects of ice-action—a feature which would be in accordance with the presence of the great transported foreign boulders found in the marine gravel of Selsea, and with the chalk boulders in the Chichester sea-beach.

While on this subject I may mention another point of interest connected with this area, which I noticed on the same occasion.

Flint implements have been found at various places, and at various elevations, in the Hampshire basin*—amongst others, in the valley of the Avon, near Fordingbridge, at an elevation of about 40 feet above the river†. Five miles north of Fordingbridge is the village of Downton. On the hill immediately east of the village is Packham Common (now enclosed); and on the right hand of the road leading from Redlinch to Standlinch Down, and passing by the north-east corner of the former common, is a small chalk-pit (see fig. 1) capped

Fig. 1.—*Section on East side of the Valley of the Avon.*
(Distance 1½ mile.)



by ochreous gravel. This consists as usual of subangular flints, and a few pebbles of quartz, with some worn fragments of iron-sandstone and flint pebbles from the adjacent Tertiary strata. It reposes upon a worn and furrowed surface of the chalk, and is from 2 to 7 feet thick. A portion of this bed had slipped down; and on examining the talus for the constituent parts of the gravel I found a small flint

* Evans, Quart. Journ. Geol. Soc. 1864, vol. xx. p. 188.
† Codrington, ibid. vol. xxvi. p. 537.

implement, very well finished, and of the ovoid type, colour, and aspect common to those found at Waren's Pit, St. Acheul. It is $3\frac{1}{4}$ inches long by $1\frac{3}{4}$ broad, finely pointed, and white, with a porcellaneous lustre. It shows no wear. I could find no other, nor any organic remains. The elevation of the pit, according to the levels obligingly furnished me by General Sir Henry James, is about 200 feet above the river, which is here 115 feet above the sea-level.

Between this pit and the river are two other well-marked broad gravel terraces, in the lower one of which mammalian remains have been found abundantly in other parts of the Avon valley. The section is as in fig. 1.

The level of the lower terrace is from 30 to 70 feet above the river, of the second from 150 to 180 feet, and of the third or upper terrace about 200 to 250 feet.

This discovery is in keeping with that of the flint implements in the gravel of the cemetery at Salisbury, which Mr. Evans estimates at 110 feet above the river, and with those of Southampton Common, which Mr. Codrington places at an elevation of 86 and 150 feet above the river at Southampton. The difference, with the first-named of these spots especially, is that there the flint implements are of the rudest pattern and make, whereas at Downton the implement is of the neatest and best-finished construction, although the gravel is one of the oldest in the district, being prior to the excavation of the valley to the greater depth of some 200 feet, to the spread of the lower gravels, and apparently to the great development of the Postglacial mammalia.

DISCUSSION.

Mr. CODRINGTON stated that, according to the Ordnance Survey, the level of the pit at Cams Wood was not more than 100 feet above the sea, so that it was at about the same level as the gravels of Titchfield and elsewhere.

Mr. EVANS remarked that the flint flake from Cams Wood presented no characters such as would prove it to be of palæolithic age. He was, on the contrary, inclined to regard it as having been derived from the surface. He commented on the height at which the Downton implement had been discovered, which was, however, not so great but that the containing gravels might be of fluviatile origin.

Mr. GWYN JEFFYEYS thought that if the beds at Cams Wood were marine, some remains of marine organisms might be found in them. If these were absent, he should rather be inclined to regard them as fluviatile.

Mr. J. W. FLOWER contended that the gravel at Downton could not be of fluviatile origin. He thought, indeed, that the gravel was actually at a higher level than the present source of the river. If this were so, he maintained that the transport of the gravel by fluviatile action was impossible. He further observed that gravels precisely similar, also containing implements, had now been found, as well in the Hampshire area as elsewhere, the transport of which, in his view, could not possibly be attributed to any existing rivers.

At Southampton they occur 150 feet above the river Itchen and the sea and considerably inland, at Bournemouth on a sea-cliff 120 feet in height, and at the Foreland (at the eastern extremity of the Isle of Wight) on a cliff 82 feet above the sea and far remote from any river. If, therefore, these deposits were effected by fluviatile agency, it was evident that all traces of the rivers were afterwards effaced by some great geological changes; or, in the alternative, some great geological change, not fluviatile, must have caused the deposit. Upon the whole, he was disposed to conclude, with the French geologists as well as with many eminent Engish authors, that the accumulation of all these superficial drifts was, as the late Sir Roderick Murchison had said, sudden and tumultuous, not of long continuance; and thus it was such as would result from some kind of diluvial action, rather than from the ordinary long-continued action of water.

Mr. Judd pointed out, in contravention of Mr. Jeffreys's views, that in the Fen-district, over large tracts of gravel of undoubtedly marine origin, there are many pits without a trace of marine shells.

Mr. Prestwich, while willing to concede that the implement-bearing gravel beds had been deposited under more tumultuous action than that due to rivers of the present day, was still forced to attribute the excavation of the existing valleys and the formation of terraces along their slopes to river-action. He showed that Mr. Flower's argument as to the present level of the source of the river was of no weight, as the country in which it had its source was formerly, as now, at a much higher level than the gravel at Downton. As to the absence of marine shells at Cams Wood, he cited a raised beach in Cornwall which, in company with Mr. Jeffreys, he had examined for a mile without finding a trace of a shell, though for the next half mile they abounded. There was the same difference between the raised beaches at Brighton and at Chichester. He was obliged to Mr. Codrington for his correction as to the level at Cams Wood, though the pit was at a higher elevation than the one to which Mr. Codrington had alluded.

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2. *On some undescribed* Fossils *from the* Menevian Group *of* Wales.

By Henry Hicks, Esq., F.G.S.

[Abstract*.]

In this communication the author gave descriptions of all the fossils hitherto undescribed from the Menevian rocks of Wales. The additions made to the fauna of the Lower Cambrian rocks (Longmynd and Menevian groups) by the author's researches in Wales during the last few years now number about fifty species, belonging to twenty-two genera, as follows:—

* The publication of this paper is deferred.

Trilobites, 10 genera and 30 species.
Bivalved and other Crustaceans, 3 genera and 4 species.
Brachiopods, 4 genera and 6 species.
Pteropods, 3 genera and 6 species.
Sponges, 1 genus and 4 species.
Cystideans, 1 genus and 1 species.

By adding to these the Annelids, which are plentiful also in these rocks, we get seven great groups represented in this fauna, the earliest known at present in this country. By referring to the Tables published in M. Barrande's excellent new work on Trilobites, it will be seen that this country also has produced a greater variety, or, rather, representatives of a greater number of groups from these early rocks, than any other country. The species described included *Agnostus*, 5 species; *Arionellus*, 1 species; *Erinnys*, 1 species; *Holocephalina*, 1 species; *Conocoryphe*, 2 species; *Anopolenus*, 2 species; *Cyrtotheca*, 1 species; *Stenotheca*, 1 species; *Theca*, 2 species; *Protocystites*, 1 species, &c. The author also entered into a consideration of the range of the genera and species in these early rocks, and showed that, with the exception of the Brachiopods, Sponges, and the smaller Crustacea, the range was very limited.

A description of the various beds forming the Cambrian rocks of St. David's was also given, and proofs adduced to show that frequent oscillations of the sea-bottom took place at this early period, and that the barrenness of some portions of the strata and the richness of other parts were mainly attributable to these frequent changes.

Discussion.

Mr. Gwyn Jeffreys suggested that the term Polyzoa might be adopted in preference to that of Bryozoa, as being the more ancient term, and that the name *Proserpina* should not be applied to the new genus of Trilobites, as it had already been appropriated to a tropical form of land-shell.

Mr. Hicks thanked Mr. Jeffreys for his suggestions, which he was inclined to adopt.

December 20, 1871.

Frederick H. Bowman, Esq., F.R.A.S., F.C.S., of Halifax, Yorkshire, and Thomas Charles Sorby, Esq., F.R.I.B.A., of 27 Brunswick Square, W.C., were elected Fellows of the Society.

The following communications were read:—

1. A letter from G. Milner Stephen, Esq., F.G.S., to the late Sir Roderick Murchison, dated Sydney, 5 October, 1871, from which the following is an extract:—

"As I regard yourself as the *prophet* of gold-discovery in Australia &c., I cannot refuse myself the pleasure of asking you to become the medium of my communicating to the Geological Society of London two very interesting discoveries recently made in this hemisphere.

"1. That of *gold* on the banks of the River Bondé on the N.E. coast of *New Caledonia.* It was discovered by a party of four men (two being Australian miners), in consequence of a splendid reward offered by the French Government in the island for the discovery of a gold-field. The head of the party brought up to Sydney about 2½ tons of auriferous drift which was highly charged with very fine, almost invisible, gold-dust; and having seen my two patent machines he offered me one-fifth of their grant of 500 *hectares* for a 'plant' of the machines and steam-engine. Accordingly I accepted the offer, having ascertained from the Master of the Mint that the auriferous drift contained about 16 *oz. to the ton* ! And my son, who is now in the island watching over our interests, finds my expectations quite confirmed, and predicts a fortune and the near proximity of a quartz 'reef,' having recently found a small quartz-boulder studded with *coarse gold.*

"I shall be much surprised if they do not shortly find the ordinary quartz-veins, and of great richness, as the micaceous sandstone containing three fourths of the gold they are getting at present bears evidences of being the débris and sedimentary deposit of rich gold-bearing rocks.

"No. 2 discovery is the very recent one of what I believe to be an enormous deposit of tin-ore, in pepitas, crystals, and beds of conglomerate, and especially in micaceous granite, more or less decomposed. Small specimens I send you herewith by a Sydney merchant (Mr. Ed. Chapman), who proceeds 'over land' from India, and can only burthen himself with a tiny parcel. I promise myself the gratification of sending to the Geological Society some large specimens by the first eligible opportunity.

"The centre of this deposit (which extends at least some miles) is about 29° 40′ S. latitude and 151° 20′ E. longitude, being in the district of New England, and about 15 miles E. from the township of Inverell on the borders of the Macintyre River. The country is granitic, with whinstone.

"I had long ago heard from a correspondent of this tin-deposit having been discovered by a shepherd, but did not believe it was of such prodigious value as I now know it to be. I shall probably visit the locality shortly, and will then give a more detailed account of a discovery which I believe will sensibly affect the markets of the world, as regards this most useful metal.

"By assay the 'peroxide' proves to be very rich in metal, about 75 per cent."

Discussion.

Mr. D. Forbes stated that in 1859 he had placed in his hands some specimens of granite from the district the discovery of tin in which was announced by Mr. Stephen, and that he found them to be perfectly identical with the stanniferous granites of Cornwall, Spain, Portugal, Bolivia, Peru, and Malacca, which he had also examined. These granites were all composed of white orthoclase felspar, colourless or black Muscovite mica, and quartz. He was not aware that tinstone (cassiterite or oxide of tin) occurred anywhere in rock of a different character. It was always accompanied by more or less native gold.

Mr. Pattison remarked that in many places where tin occurred it was not present in sufficient quantity to be remuneratively worked.

Mr. D. Forbes, in answer to a question from Prof. Ramsay, stated that, as far as could be ascertained, the age of the stanniferous granites mentioned by him must be between the end of the Silurian and the early part of the Carboniferous period.

Prof. Ramsay would carry them down to the close of the Carboniferous period, and would be contented to term them pre-Permian.

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2. Remarks *on the* Greenland Meteorites.

By Professor A. E. Nordenskiöld, For. Cor. G.S.

The meteorites which I discovered at Ofivak, in Greenland, in 1870, most of which have now been brought home by the expedition of this year under the command of Baron v. Otter, seem to have formed the principal masses of an enormous meteoric fall, which took place during the Miocene period, extending over an immense area (some 200 English miles) not only of the region occupied by the Greenland basalt, but also where the country is composed of granite-gneiss.

The native iron is very variable in appearace; but as far as I yet can judge, it is free from silicates, notwithstanding that pieces of basalt (apparently?) are imbedded in the exterior of the blocks, apparently filling cavities in the outer surface of the original meteorites.

The basalt at a distance from this locality does not contain any native iron; it is only in the immediate vicinity of the iron masses themselves that native iron along with pebbles is found in the basalt, which at this place is clearly seen to be a subsequently consolidated basalt-tuff and not congealed lava.

That this iron is of eruptive origin appears impossible to me, because:—(1) the iron, upon being heated, evolves gaseous matter even up to as much as 100 times the volume of the iron itself; (2) it contains distinct isolated particles of sulphide of iron, which are imbedded in the rest of the mass of iron, which in itself is free or nearly free from sulphur; (3) the external form of the iron masses themselves does not show evidences of their having been poured out, when in the molten condition, into a cavity or fissure.

The character of the iron masses is extremely variable, as they are in part composed of meteoric nickeliferous cast iron, or of meteoric nickeliferous wrought iron, or mixtures of both; in which last case the so-called Widmannstætten's figures are found to be best developed.

The native iron found in the basalt occurs:—

A. As enclosed and but little altered meteoric stones.

B. Filling up cracks from one to two lines in width, and being either fragments of meteorites flattened out under the influence of time, or wedged into these cracks in the act of falling, or which have fallen into cracks in the subsequently consolidated tuff.

C. Brecciiform stones composed of fragments of the iron cemented together with hydrated oxide of iron and newly formed silicate of iron.

D. Close to the iron masses which occur in the basalt are also found enclosed fragments of a rock unlike the basalt itself, and remarkable for being rounded on the edges and having what resembles a meteoric crust on the exterior! I do not venture to express any decided opinion as to the origin of this variety.

E. As grains disseminated in the basalt, occasionally as large as peas or beans, but oftener only as fine scales, which, in my opinion, have in part been disseminated through the basaltic ash which was the material from which the present basalt was formed, and in part produced through pseudomorphic processes due to the presence of the large iron masses themselves, and which it is without doubt easier to explain than to account for the tin-ore (cassiterite) pseudomorphs of orthoclase found in Cornwall.

The great mass of the Greenland basalt is without doubt only consolidated beds of basaltic ashes.

Within an area of at most 50 square metres 15 meteorites were found, which weighed as follows in Swedish pounds:—50,000, 20,000, 9000, 336, 230, 200, 191, 150, 150, 100, 56, 42, 15, 8, and 6, the three largest being in their diameter respctively 2 by 1·7 metres, 1·3 by 1·27 metre, and 1·15 by 0·85 metre. About 100 lbs. of lenticular-shaped fragments of iron, from 3 to 4 inches thick, were also extracted from the basalt dyke close at hand.

The following analyses show the chemical composition of the iron:—

	Part of one of the largest blocks, A. E. Nordenskiöld.	Of a lesser block, Th. Nordstrom.	Of iron from the basalt, G. Lindstrom.
Iron	84·49	86·34	93·24
Nickel	2·48	1·64	1·24
Cobalt	0·07	0·35	0·56
Copper	0·27	0·19	0·19
Alumina	trace	0·24	....
Lime	trace	0·48	....
Magnesia	0·04	0·29	trace
Potash	trace	0·07	0·08
Soda	trace	0·14	0·12
Phosphorus	0·20	0·07	0·03
Sulphur	1·52	0·22	1·21
Chlorine	0·72	1·16	0·16
Silica	trace	0·66	0·59 (Silica and Insoluble)
Insoluble	0·05	4·37	
Carbonic organic matter water (and loss)	10·16	3·71	C 2·30; H 0·07
	100·00	99·93	99·79
Sp. gravity	6·36 & 5·86	7·05 & 7·06	6·24

Analysis of the insoluble silicate by Nordstrom :—

	From the largest blocks.		Of rock attached to the outside of largest block.
Silica	61·79	....	44·01
Alumina	23·31	....	14·27
Sesquioxide of Iron	1·45	....	3·89
Protoxide of Iron	....	....	14·75
Magnesia	2·83	....	8·11
Lime	8·33	....	10·91
Potash } Soda }	2·29	....	{ 0·97
			{ 2·61
	100·00		99·52

DISCUSSION.

Mr. ROBERTS protested against the evolution of gaseous matter being considered a proof of meteoric origin.

Prof. RAMSAY reiterated his previously expressed opinion, that the masses of iron might be of telluric origin.

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3. *Further Remarks on the* RELATIONSHIP *of the* XIPHOSURA *to the* EURYPTERIDA *and to the* TRILOBITA *and* ARACHNIDA. By HENRY WOODWARD, Esq., F.G.S., F.Z.S.

I HAD, on a former occasion (November 21, 1866), the honour to communicate a paper to this Society "On some points in the structure of the Xiphosura having reference to their relationship with the Eurypterida"*, in which were discussed the grounds for the union of these two suborders (afterwards dealt with in greater detail in the monograph of the Merostomata in the Palæontographical Society's publications for 1866). I therefore venture to think it may not be considered inappropriate if I bring the subject again under your consideration after an interval of five years, during which time some considerable additions have been made to our knowledge of this group.

The papers to which I shall have occasion especially to refer are the following:—

1. "On a New Limuloid Crustacean (*Neolimulus falcatus*) from the Upper Silurian of Lesmahagow, Lanarkshire." By H. Woodward. (Geol. Mag. 1868, vol. v. pl. i. fig. 1, p. 1.)

2. "On some new Species of Crustacea from the Upper Silurian Rocks of Lanarkshire, and further Observations on the Structure of *Pterygotus*." By H. Woodward. (Quart. Journ. Geol. Soc. 1868, vol. xxiv. pls. ix. & x., p. 289.)

3. "Notes on some Specimens of Lower Silurian Trilobites." By E. Billings, F.G.S. (Quart. Journ. Geol. Soc. 1870, vol. xxvi. pls. xxi. & xxii., p. 479.)

4. "Note on the Palpus and other Appendages of *Asaphus* from

* Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 28.

the Trenton Limestone, in the British Museum." By Henry Woodward. (Quart. Journ. Geol. Soc. 1870, vol. xxvi. p. 486.)

5. "The Horse-foot Crab." By the Rev. S. Lockwood, Ph.D. (American Naturalist, vol. iv. No. 5, July 1870, p. 257.)

6. "On the Embryology of *Limulus polyphemus*." By A. S. Packard, jun., M.D. Read before the American Association for the Advancement of Science, August 1870. (American Naturalist, vol. iv. No. 8, 1870, October, p. 498.)

7. Note on the Trilobite from the Trenton Limestone described by Mr. Billings in the Quart. Journ. Geol. Soc. 1870. By Prof. Dana. (Annals and Mag. Nat. Hist. for May 1871, p. 366; see also Silliman's Journal for May 1871, p. 320.)

8. "On the Structure of Trilobites." By H. Woodward. (Geol. Mag. 1871, July, vol. viii. p. 289, pl. viii.)

9. "Report of the Committee 'On the Structure and Classification of the Fossil Crustacea.'" Drawn up by Henry Woodward, and read at the Meeting of the British Association for the Advancement of Science, Edinburgh, August 1871. (Since printed in Geol. Mag. vol. viii. p. 521.)

10. "Zur Embryologie und Morphologie des *Limulus polyphemus*." Von Dr. Anton Dohrn. (Jenaische Zeitschrift, Band vi. Heft 4, p. 580, Tafeln xiv. & xv.) Received September 30, 1871.

These additions comprise:—

The discovery of a new genus of Limuloid Crustaceans (with free and moveable thoracico-abdominal segments) in the Upper Silurian of Lanarkshire, thus carrying back the Xiphosura in time to a point as remote as that of the great Eurypteridan forms which principally occur in this same stratum and locality.

The discovery of branchiæ in *Pterygotus bilobus*, var. *perornatus*, Salter (Pal. Soc. Mon. Merostomata, Part ii. 1869), and also in *Slimonia acuminata*, proving the correctness of my deductions published in the paper already referred to (Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 31, pl. ii. fig. 11).

Four *Eurypteri* and two *Pterygoti* added, namely:—

Eurypterus scorpioides, *H. Woodw.* Upper Silurian, Lanark.
—— punctatus, *Salter.* Upper Silurian, Dudley and Leintwardine.
—— obesus, *H. Woodw.* Upper Silurian, Lesmahagow.
—— Brodiei, *H. Woodw.* Upper Silurian, Perton, Herefordshire.
Pterygotus raniceps, *H. Woodw.* Upper Silurian, Lesmahagow.
—— taurinus, *Salter* (British Association Reports, Norwich, 1868, p. 78), Lower Old Red or Ledbury Shales, Hereford.

The discovery, by Mr. E. Billings, of Montreal, of what appears to be good evidence of legs in *Asaphus platycephalus* from the Trenton Limestone, further confirmed by a second specimen in the British Museum, which exhibits a similar structure, and also the remains of a small palpus at the side of the hypostome or lip-plate.

The researches of Drs. Packard and Anton Dohrn have greatly added to our heretofore very scanty knowledge of the larval stages of *Limulus*; and Dr. Lockwood contributes some interesting notes on the habits and œconomy of *Limulus polyphemus*. A short summary of these may not be thought out of place when it is remembered that the King-crabs of to-day trace back their ancestry at least to Silurian times.

The following notes on the living King-crab, or Horsefoot-crab, of N. America, *Limulus polyphemus,* are extracted from Rev. Samuel Lockwood's paper above cited.

The modern *Limulus* inhabits moderately deep water (from 2–6 fathoms), and never seeks the shallows save for the purpose of reproduction. The young, however, being unable to resist the action of the sea, are carried to and fro by the tide.

Limulus is emphatically a burrowing animal, living literally in the mud, into which it digs its way with great facility. It uses the front border of its head-shield (inflected at a sharp angle with its hinder shield) for this purpose, aided by its tail, which serves as a fulcrum. By the active use of its feet, and by alternately inflecting and straightening its carapace, it accomplishes both digging and subterranean progression. It is carnivorous in its habits, feeding upon any of the soft-bodied Nereids and other mud-dwelling annelides and mollusca which it meets with.

Dr. Lockwood finds that the King-crab, when caught by one of its legs, does not attempt to free itself by casting off the imprisoned limb, as a crab or lobster would do under similar circumstances. The leg of the Decapod, however, is not homologous with that of *Limulus,* whose organs of locomotion are modified palpi or maxillipeds rather than true feet, all its walking-appendages being mouth-organs at their proximal end, which would render their replacement in *Limulus* as difficult as would be that of the maxillæ or maxillipeds in a Decapod Crustacean.

It, however, exuviates like other members of the Crustacean class, five or six times at very short intervals during the first year, and afterwards about twice annually.

From an actual experiment made by the Rev. Samuel Lockwood it would appear that the female King-crab spawns twice every year, the breeding-season being during the months of May, June, and July. They come up during the great high tides, spawning under water near the high-water mark; thus the eggs are daily exposed to the sun's warmth for a short time at low water.

At this season they come up in great numbers in pairs, the male grasping the sides of the female's shield with his strong and peculiarly modified chelate antennæ.

The eggs, measuring fully half a pint in quantity, and about the size of millet seed, are deposited by the female in a hole in the sand, and are fecundated by the male *after deposition,* and then left to hatch.

This is unlike the behaviour of any other of the Crustacea, which, as a rule, appear to fecundate the ova by a true union before the eggs are discharged from the ovaries*.

The eggs, moreover, in the Crustacea (with the exception of the genus *Squilla* and a species of *Gecarcinus*) are usually borne by

* [According to a paper read by M. Chantran to the French Academy of Sciences on January 15th, 1872, the eggs of the common Crayfish are fecundated after expulsion from the oviducts.—Ed. Q. J. G. S.]

the female either in an egg-pouch, or *marsupium*, formed by a modification of a certain number of pairs of appendages, or adhering by a viscous secretion to the hairs of the abdominal feet (as in the Crab, Lobster, and Prawn), until they are hatched.

The ovipositing of *Limulus* may serve to explain the origin of the masses of fossil eggs met with in the shales of the Old Red Sandstone of Forfarshire and of Trimpley, near Bewdley, Worcestershire, formerly called *Parka decipiens*, and now referred to *Pterygotus*; for the Eurypterida, like the Xiphosura, may also have left their eggs in the shallows to hatch.

From the experiments of Dr. Lockwood it would appear that the eggs of *Limulus* are slow to hatch. Thus a batch which he preserved occupied seventy days after spawning before hatching*; whilst some, set aside at the end of the season in a jar of salt water, hatched out *after some three hundred and fifty days* from the time of spawning.

He very justly estimates the rate of hatching to be due to the greater or less exposure to light and warmth and to the oxygenation effected by the constantly shifting tide-wave and the occasional exposure in damp sand or mud to the sun's rays at low water.

This exceeding vitality and fecundity may best explain the persistence of this genus in time, a persistence probably unsurpassed by any among the Crustacean class, save the Entomostraca alone.

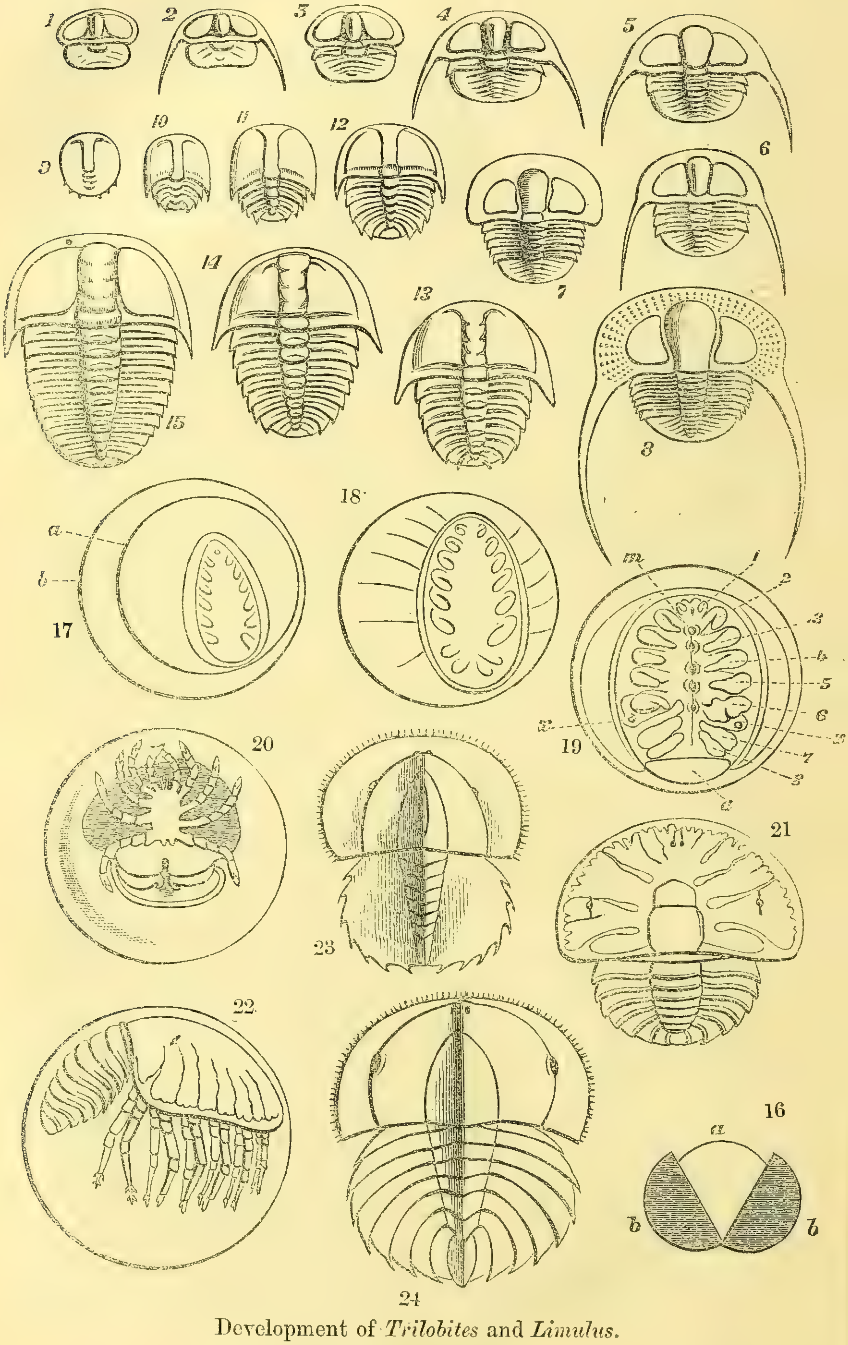
Embryology of Limulus.—We are in possession of three separate accounts of the embryology and larval development of *Limulus*—from the Rev. Samuel Lockwood, Dr. A. S. Packard, jun., and Dr. A. Dohrn. The last of these is the most elaborate treatise, and gives the most carefully prepared figures. I will beg leave to select as complete an account as possible from the two latter writers, Dr. Lockwood being unable to carry on a microscopic examination, a disability we all must regret, inasmuch as he was resident all the summer on the coast, and had hundreds, if not thousands, of fertilized eggs to experiment upon in his hatching-jars. His drawings, however, are full of interest.

The eggs measure ·07 of an inch in diameter, and are green in colour. Each egg is enclosed in a double skin—the thick outer one called by Dohrn the "*exochorion*" (*b*), the inner the "*chorion*" (*a*) (by Packard the outer the "*chorion*," and the inner the "*amnion*" and also the "*blastoderm-skin*"). (See page 50, fig. 16.)

The earliest stages were noted by Packard. "Only one or two eggs were observed in process of segmentation. In one the yelk was subdivided into three masses of unequal size. In another the process of subdivision had become nearly completed."

1*st stage.*—"In the next stage observed, the first indications of the embryo consisted of *three* minute, flattened, rounded tubercles—the two anterior placed side by side, with the third immediately behind them. The pair of tubercles probably represent the first pair of limbs, and the third single tubercle the abdomen."

* Dr. Packard makes the time of hatching *six* weeks only.



Development of *Trilobites* and *Limulus*.

EXPLANATION OF ILLUSTRATIONS.

Figs. 1–8. *Trinucleus ornatus*, Sternb. sp. (copied from Barrande's 'Système Silurien du Centre de la Bohême," Prague, 1852, 4to, plate 30). Specimens arranged in series according to their supposed age. (All the stages figured by Barrande are not given here.)

1. Young individual, destitute of thoracic segments, composed of head-shield and pygidium only.
2. Another of the same stage, in which the genal or cheek-spines are developed.
3. Individual with one thoracic segment developed, but without the genal spines.
4. Another of the same stage, with the genal spines.
5. Individual with two thoracic segments, and in which the genal spines are present.
6. Individual with three thoracic segments, and possessing the genal spines.
7. Individual with five thoracic segments, but without genal spines.
8. Adult *Trinucleus*, with six thoracic segments and fully developed genal spines.

9–15. *Sao hirsuta*, Barrande (copied from plate 7 of Barrande's work above cited). Barrande figures twenty stages of this Trilobite, of which we have only reproduced seven.

9. First stage. A young individual in which the limit of the head-shield is not indicated as separating it from the pygidium.
10. Second stage. Young individual with the head-shield separated, and having indications of three soldered segments to the pygidium.
11. Third stage, in which the genal angles of the head and the spiny border of the pygidium are well seen, and four or five soldered segments indicated.
12. Fourth stage, in which two free thoracic segments are developed behind the head, and two or three soldered segments represent the pygidium.
13. Fifth stage, in which the thorax is longer than the head, and is composed of three movable segments and three soldered segments in the pygidium.
14. Sixth stage, in which four free segments succeed the head, and three or four soldered segments form the pygidium.
15. Tenth stage, in which eight free segments succeed the head, and three soldered segments form the pygidium. [In the twentieth stage figured by Barrande the adult has seventeen free thoracico-abdominal segments and two soldered ones (the pygidium).]
16. Egg of *Limulus polyphemus*: *a*, the chorion; *b*, the exochorion (after Dohrn).
17. Third stage in the embryo of *Limulus*: *a*, chorion; *b*, exochorion (after Packard).
18. Fourth stage (?) in the embryo of *Limulus* (after Dr. Packard's figure).
19. Fourth stage (?) in the embryo of *Limulus*: 1, antennules; 2, antenna; 3–6, maxillipeds; 7 and 8, thoracic plates afterwards bearing the branchiæ; *m*, the mouth; *x*, the ovarian apertures (?); *a*, the abdomen (after Dohrn).
20. Fifth stage (?) of embryo of *Limulus* (after Dohrn). At this stage the exochorion is split, and the chorion is expanded by the admission of water by endosmose, in which the embryo is seen to revolve.
21. Ninth stage (?) of embryo, "just before hatching" (after Packard): dorsal aspect.
22. The same: side view of embryo.
23. Larva of *Limulus* recently hatched (after Packard).
24. Larva of *Limulus* on hatching (the "*Trilobitenstadium*" of Dohrn).

2nd stage.—"In more advanced eggs three pairs of rudimentary limbs were observed, the most anterior pair* being much smaller than the rest. The mouth-opening is situated just behind them."

3rd stage.—"In a succeding stage [of which Dr. Packard gives a figure] the embryo forms an oval area surrounded by a paler-coloured areola, which is raised into a slight ridge. This areola is destined to be the edge of the body or line between the ventral and dorsal sides of the animal. There are six pairs of appendages, forming elongated tubercles, increasing in size from the head backwards; the mouth is situated between the anterior pair." (See p. 50, fig. 17.)

4th stage.—At this stage we have figures and descriptions both from Drs. Dohrn and Packard, the former of whom has prepared most excellent plates, the paper of the latter being illustrated by clear, sharp, woodcut outlines only.

"The oval body of the embryo has increased in size; the separation into cephalothorax and abdomen has taken place; the mouth-opening is seen, and the rudimentary six pairs of appendages are readily made out. The first pair are well marked by their position in front of the mouth and their minute size; in like manner, the sixth pair are distinguished by their greater development and modified form." Dr. Dohrn also detects in this stage the under lip†; but his drawing does not show it very clearly. This is followed by the rudiments of the first thoracic plate bearing in the adult the ovaries and marked in the embryo by two pores (*x*). Behind these come the rudiments of the first two pairs of branchiferous plates, not yet outspread. The abdomen (*a*) is then, as afterwards, destitute of appendages. (See page 50, figs. 18 & 19.)

5th stage.—Dr. Dohrn alone seems to have observed the next succeeding stage.

He represents the ventral aspect; in the background we see two bodies only—one being the head-shield, the other the thorax and abdomen (?), or at least their rudiments; *no segmentation*, however, is shown in these divisions. (See page 50, fig. 20.)

The limbs are as well developed as those of an *Acarus*, which this form somewhat resembles. The antennules are exceedingly small, and have no chelæ; the other limbs appear to be six-jointed and to possess small chelæ at their extremities (*enclosed in a sheath*). The rudimentary bilobed metastoma (under lip) is also to be discerned at the base of the sixth pair of appendages.

The *thoracic plate* is now of some size, and, although strongly bilobed, is of sufficient extent to conceal the ovarian openings. Two (?) branchiferous plates follow.

[This was probably the stage observed by Dr. Milne-Edwards in 1838, and referred to in my paper, Quart. Journ. Geol. Soc. 1867, vol. xxiii. pl. ii. figs. 3 and 4, p. 34. Dr. Milne-Edwards's description seems to be *fully* borne out by Dohrn and Packard.]

6th stage.—We are rather at a loss whether to consider this a distinct stage, Dr. Packard having seen the *dorsal aspect* of the em-

* The antennules.—H. W.

† Metastoma.—H. W.

bryo apparently to greater advantage than Dr. Dohrn, who has given us two admirable ventral views and a *much more advanced* dorsal aspect.

"This stage is signalized," says Dr. Packard, "by the more highly developed condition of the dorsal portion of the embryo and the increase in size of the abdomen*, and the appearance of *nine* distinct segments to it. The segments of the cephalothorax are now very clearly defined, as also the division between the cephalothorax and the abdomen, the latter being now nearly as broad as the cephalothorax, the sides of which are not spread out as in a later stage."

"At this stage the egg-shell (*exochorion*, Dohrn) has burst, and the 'amnion' (*chorion*, Dohrn) increased in size several times its original bulk, and has admitted a corresponding quantity of sea-water, in which the embryo revolves."

7th stage.—"At a little later period the embryo throws off an embryonal skin, the thin pellicle floating about in the egg." (Packard.)

8th stage.—"Still later in the life of the embryo the claws are developed, an additional rudimentary gill appears, and the abdomen * grows broader and larger, with the segments more distinct."

9th stage.—"Just before hatching, the cephalothorax spreads out, the whole animal becomes broad and flat, the abdomen *, being a little more than half as wide as the cephalothorax †. The two eyes and the pair of ocelli on the front edge of the cephalothorax † are distinct; the appendages to the gills appear on the two anterior pairs; the legs have increased in length, though only a rudimentary spine has appeared on the coxal joint, corresponding to the numerous teeth in after life. The trilobitic appearance of the embryo is most remarkable. It also now closely resembles the Xiphosuran genus *Belinurus*. The cardiac or median region of the head-shield is prominent and convex. The lateral regions are more distinctly marked on the abdomen* than on the cephalothorax†. The six segments of the cephalothorax† can with care be distinguished; but the nine abdominal segments * are most clearly demarked; and in fact the whole embryo bears a very near resemblance to certain genera of Trilobites, as *Trinucleus, Asaphus*, and others." (See p. 50, figs. 21 & 22.)

10th stage.—The young *Limulus*, upon emerging from the egg, differs chiefly from the previous stage in the abdomen* being much larger, scarcely less in size than the cephalothorax †, and in the larger size of the gills. The abdominal spine is still rudimentary, forming only a small lobe varying in length, but scarcely projecting beyond the abdomen. It forms, in fact, the ninth segment ‡.

"At this stage," Dr. Packard observes, "the young swim briskly up and down the jar, skimming about on their backs by flapping their gills, not bending their bodies."

11th stage.—"In a succeeding moult, between three and four weeks after hatching, the abdomen * becomes smaller in proportion

* Thoracico-abdominal segments.—H. W.

† Cephalic plate.—H. W.

‡ This is the *Trilobitenstadium* of Dohrn.

to the cephalothorax*; and the abdominal spine is prominent, being ensiform and about three times as long as broad."

12*th stage.*—"At this, and also in the second or succeeding moult, which occurs about four weeks after the first, the young *Limulus* doubles in size."

I now beg leave to say a few words as to the conclusions arrived at by these authors.

Of the Rev. Dr. Lockwood's paper, it may be remarked that his acute observations as to the likeness of the *Limulus*-embryo to young Trilobites and also to *Pterygotus* and *Eurypterus*, are those of a man who catches at the main features of any form of structure, and at once is able to call to mind a comparison, although not always the correct one. His remarks are, however, of great value, and many of his figures of the young of *Limulus* are of much interest.

His comparison of the posterior shield, composed of the thoracico-abdominal segments, with the "telson" or "pygidium" of *Pterygotus* shows that he has not ascertained their relation to the rest of the structure of the animals so compared.

Dr. Packard, after referring to the dense chorion of the egg in *Limulus*, which splits and is thrown off during the development of the embryo within the inner egg-membrane ("amnion" or "blastoderm," Packard), observes that the primitive band, unlike that of the Crustacea generally, is confined to a minute area, and rests upon the top of the yelk, as in the spiders and scorpions and certain Crustacea (namely, *Eriphia spinifrons* and *Astacus fluviatilis, Palæmon adspersus* and *Crangon maculosus*), in which there is no metamorphosis.

"The embryo," says Dr. Packard, "is a Nauplius; it sheds its Nauplius-skin about the middle of its embryonic life. This Nauplius-skin corresponds," he considers, "in some respects to the 'larval skin' of German embryologists." But he adds, "the recently hatched young *Limulus* can scarcely be considered a Nauplius (like the larvæ of the Phyllopoda), but is to be compared to those of the Trilobites" (*e. g. Trinucleus ornatus*, *Sao hirsuta*, and *Agnostus nudus*), which, in the youngest condition observed by Barrande, have only the head and pygidium, the thoracic segments being added at subsequent moults. Dr. Packard thinks that the circular larva of *Sao hirsuta* approaches nearest to the Nauplius-form of the Phyllopods, though he contends that it is not a Nauplius.

He adds, "the larva passes through a slightly marked metamorphosis. It differs from the adult simply in possessing a less number of abdominal feet [*thoracic* branchiferous feet, H.W.] and in having only a rudimentary spine."

"Previously to hatching, it strikingly resembles *Trinucleus* and other Trilobites, suggesting that the two groups should, on embryonic and structural grounds, be included in the same order, especially now that Mr. E. Billings has demonstrated that *Asaphus* possessed eight pairs of five-jointed legs of uniform size."

[I shall presently take occasion to show the inconsequence

* Cephalic plate.—H. W.

of this last suggestion; but before doing so it will be desirable to record Dr. Dohrn's views.]

It is to be regretted that Dr. Anton Dohrn (who has paid so much careful attention to the embryology of the Arthropoda, and whose valuable contributions on this subject have already appeared in the 'Jenaische Zeitschrift,' and are no doubt well known), had only specimens preserved in spirits for examination, which prevented him from fully completing his researches. He, however, deserves our best thanks for what he has accomplished with the materials at his disposal.

Having already described the larval stages. I will pass at once to the conclusions he has arrived at as to the position of *Limulus* with regard to the other Crustacea.

Whether *Limulus* does or does not descend from a Nauplius, Dr. Dohrn considers that at present we have no knowledge of a Nauplius-stage in that genus, any more than in the Trilobita; but the *subsequent stages* agree with such forms as *Trinucleus* and *Sao*, in the gradual development of the young from a form having a simple cephalic and caudal plate to the adult stage in which numerous intermediate body-rings have been added.

Dr. Dohrn further concludes that *Limulus* cannot be retained among the Crustacea, for two reasons:—

1st. Because of the presence of *only one pair of extremities* which receive their nerve-system from the supraœsophageal ganglion *.

2ndly. From the position and form of the under lip.

1. Bearing in mind that *all Crustacea* have two pairs of antennæ receiving nerves from the supraœsophageal ganglion, thus distinguishing them from the spiders, Myriopoda, and insects, it is (says Dr. Dohrn) impossible to ignore that the presence of only one pair of extremities (the antennules) in *Limulus* so supplied with nerves separates it from the Crustacea. And, further, to which of the two pairs of antennæ, and therefore to which of the two anterior pairs of extremities, in Nauplius does this first pair in *Limulus* correspond? And this question we must leave entirely unanswered, as we have at least hitherto been unable to detect any trace of a rudimentary second pair either before or behind this first pair."

Dr. Dohrn therefore concludes that *Limulus* cannot be retained with the Crustacea, but must be classed with spiders and insects which have only one pair of antennæ.

2. With regard to the under lip (metastoma), Dr. Dohrn says that in all the Crustacea it is a fold of the germinal membrane behind the mouth. It is found on a level with the mandibles, or sometimes even in front of them. In *Limulus* the under lip is *behind* the sixth pair of appendages, and *is divided into two parts.*

This led Dr. Dohrn to suspect that it might prove to be really *a seventh pair of appendages*; but this point he has been unable to clear up; for, owing to the fact of his specimens having been in

* This was first pointed out by Van der Hoeven, in his 'Recherches sur l'Histoire Naturelle et l'Anatomie des Limules,' 1838.

spirit, he could not satisfactorily make out whether or not it has a separate nerve-ganglion.

He, however, concludes that "these two peculiarities make it improbable that *Limulus* belongs to the Crustacea."

Dr. Dohrn remarks that "what Savigny has hinted at, and what Strauss-Dürckheim has one-sidedly expressed, reappears now under the light of the theory of evolution." The connexion of the Arachnida with the Crustacea is probably through *Limulus* and the Eurypterida, as indicated by myself in 1866 (see Quart. Journ. Geol. Soc. vol. xxiii. *loc. cit.*).

In comparing the *Limuli* and *Eurypteri* with the Arachnida one naturally turns to the Scorpionidæ as the group most suitable for that purpose.

Both in *Pterygotus* and *Scorpio* we find the antennary system modified in the same manner, not only in form but in function also; the larval ocelli are seen in both; the locomotory appendages are all cephalic in both; and the elongated body, with its peculiar trapezoidal head-shield, its enlarged thoracic segments (the first in both) bearing the reproductive organs on the underside, and the more slender abdominal series followed by a broad apiculated tail-joint, naturally seems to invite a comparison of the two groups. But the respiration in the former is performed aërially by tracheal openings distributed in pairs along the ventral borders of the thoracic segments; whereas in *Limulus* and *Pterygotus* the respiration is performed by branchiæ borne on the same series of segments (the thoracic) in *Limulus*, and by one or two only of the same in *Pterygotus*. But, on the other hand, the great cordiform under lip of *Pterygotus* and the two pieces homologous therewith in *Limulus*, the broad thoracic plate or operculum in both *Limulus* and *Pterygotus*, and also the large compound eyes and the respiratory system in both, differ entirely from any thing occurring in the Arachnida. I have long suspected that the organs called combs in the Scorpion may be homologous with the branchial leaves of *Pterygotus*: they are, so far as we are aware, aborted organs in *Scorpio*, although they have been supposed to fulfil some excitatory function in connexion with the impregnation of the ovaries; but I can find no evidence upon the subject.

As I have elsewhere stated, there is no insuperable difficulty in accepting, on sound physiological grounds, the possibility of any animal passing through larval conditions, casting aside at even a single moult its branchiæ, and assuming aërial respiration, quitting the water and inhabiting the land, changing its element, its diet, its mode of progression, and its entire life. Such cases are familiar to the entomologist *, the carcinologist †, and even to the herpetologist ‡.

From the examination of the embryonal changes of *Limulus* Dr. Dohrn has already been able to prophecy much; and no doubt more will follow from his researches, if he obtains better specimens.

He sees, however, how remarkably the young stages agree with

* Larval and adult Libellulæ, Ephemera, &c.

† *Gecarcinus ruricola* and other land-crabs.

‡ The Batrachia.

the youthful *Sao hirsuta* and *Trinucleus ornatus*; indeed, he might well add, with the young of *Agnostus*, *Aulacopleura*, *Phacops*, *Hydrocephalus*, and with every other Trilobite with whose young stages the illustrious Barrande has made us acquainted.

He also notices the remarkable analogy which the nearly mature embryo presents to *Belinurus* and *Prestwichia*—a resemblance which I pointed out in my paper (already referred to and read before the Society in November 1866).

Dr. Dohrn refers to Prof, Huxley's memoir on *Pterygotus* (published in the Memoirs of the Geological Survey, Monograph I., on the Eurypterida, 1859) to show that at that time Prof. Huxley saw no possibility of combining the Eurypterida with the Xiphosura. But, considering the materials within Prof. Huxley's reach, as compared with those which it has been my good fortune to have the advantage of studying, it is hardly fair to condemn the classification of the *later* writer upon the opinion of a high zoological authority (like that of Prof. Huxley) published nine years before that in which the monograph on the Merostomata appeared.

I have long been aware that Prof. Huxley has concurred in my classification of this group, and in his latest published "Synopsis of the Animal Kingdom" (in Jukes's 'Manual of Geology,' dated 1872), he has adopted the order Merostomata for "King-crabs, *Eurypterus*, &c."

Prof. Häckel believes the Trilobites to be a suborder of the Phyllopoda, from which *perhaps* the Pœcilopoda descended. He again divides the Pœcilopoda into two legions, viz. the Xiphosura and Gigantostraca *.

In this view Gegenbaur agrees with Häckel.

I will now quote the final paragraph from Dr. Dohrn's paper, and then give my reasons for dissenting from his conclusions.

"The more the theory of evolution is allowed a direct influence in zoological work, the more conspicuous is its preeminently practical character, inasmuch as it not only solves problems, but also suggests a correct method of inqniry. Thus, it is true, it destroys the traditional system; but it sets up a new one immediately: and thus, if we ask for the result of its application as made in the present memoir, we arrive at the following conclusions:—

"*Limulus* is most nearly related to the Gigantostraca; both seem to be related to the Trilobites, although it is not possible to demonstrate all the details of their relationship.

"The morphologico-genealogical relations of these three families to the Crustacea cannot at present be established, and perhaps may always remain doubtful.

"It is also impossible at present to say any thing definite concerning the relationship between them and the Arachnida.

"Therefore all we can do is to combine these three families under a common name, for which I would propose Häckel's expression Gigantostraca, and to place them in the system beside the Crustacea."

* See his 'Generelle Morphologie.' The Gigantostraca being *Pterygotus*, *Eurypterus*, &c.

To conclude, then :—

1. According to Dr. Packard there is a Nauplius-stage passed by *Limulus* in the egg. (He, however, does not seem quite to understand what is meant by a Naupliiform larva.) He admits that it is not like the "Nauplius" of *Apus* or of *Branchipus*, but is to be compared rather to that of the Trilobites, a knowledge of which we do not possess.

2. If *Limulus* is brought *nearer* to Trilobita through the discovery of the specimen of *Asaphus* (recently exhibited here by Mr. E. Billings, F.G.S., the eminent palæontologist to the Geological Survey of Canada, and figured in Quart. Journ. Geol. Soc. 1870, vol. xxvi. p. 479, pls. xxxi. & xxxii.), we have failed to understand its nature. The specimen is believed to possess *eight* pairs of five-jointed walking-feet attached to the *movable* (thoracico-abdominal) segments of the body, not a series of mouth-feet (gnathopodites), as in *Limulus*, but rather like the thoracic legs in the Isopoda.

3. That which really does bring the Trilobites near to *Limulus* is the series of embryonal changes passed through by the latter in the egg, which resemble the *young* of the former, and which agree also with the young state in the Isopoda *.

4. With regard to Dr. Dohrn's investigations, much as he has done, he admits that many more points remain in uncertainty—for instance, the neurology of the embryo, the development of the lower lip, &c.

5. The Nauplius-stage, too, is left in doubt; he is only able to compare the subsequent stages with the young Trilobite and with *Belinurus* and *Prestwichia*. With these latter I had already compared the larval *Limulus* figured and described by Milne-Edwards in 1838 †.

6. Not having dissected *Limulus*, I was unable either to rebut or to confirm Van der Hoeven's and Dr. Dohrn's arguments as to the presence of only one pair of anterior extremities supplied with nerves from the supraœsophageal ganglion; but, through the kindness of Professor Owen, who has lately been carrying on, or rather renewing, some researches made long since, upon the neurology of *Limulus*, I am able to state upon his authority that *Limulus* possesses two distinct pairs of appendages (antennules and antennæ) which derive their neuration from two pairs of nerves given off from the supraœsophageal ganglion. Van der Hoeven's statement must therefore be considered incorrect ‡.

7. With regard to the Eurypterida, so far as our present know-

* From Fritz Müller's 'Facts and Arguments for Darwin' (translated and edited by Mr. W. S. Dallas, F.L.S., the Assistant Secretary to the Geological Society), it seems evident that, upon embryological grounds, many Crustacean orders and families might be united together.

† See my paper, Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 34.

‡ Professor Owen informs me that he has pointed out, in his paper on the anatomy of *Limulus* (not yet published), that he observes, in the innervation of the great ensiform caudal spine, evidences of several pairs of nerves divided into dorsal and ventral branches, which he considers can only be explained on the assumption that the spine is not a simple median appendage or terminal plate

ledge extends, I must adhere to my already published conclusion, namely that one pair of antennary organs is suppressed—a strong argument in favour of the larval character of these palæozoic forms.

8. With regard to the under lip (*metastoma*), it seems singular to base the refusal of a place to *Limulus* among the Crustacea upon the fact that the metastoma is rudimentary, whereas in *Pterygotus* it is very large, formed in one piece, having a ridge in the mesial line. In the Trilobita it is wanting, and, in place of it, we have a largely developed hypostome or upper lip fulfilling the function of assisting the maxillæ to retain the food in the same manner as does the hypostome in *Apus*. Yet the Trilobita and Eurypterida (one with a hypostome, and the other with a metastome) are placed by Dr. Dohrn together, *beside* the Crustacea. The development of this very organ in larval *Limulus* was one of the points Dr. Dohrn was unable to clear up.

9. With regard to Dr. Dohrn's application of Darwin's theory of evolution, it cannot be necessary in this place to set forth the many ways in which this doctrine has been found most serviceable to the naturalist, as offering the means of solution to many a "Gordian knot"—sometimes untying it for us with the greatest ease—at other times (and possibly in this case), cutting it with equal facility.

It is no difficult matter to pull down a system of classification; but it is only right to demand that this should not be done upon insufficient grounds.

Heretofore, in the formation of zoological groups, it had been the custom (long before embryology became so important a branch of study, or was so well understood as it is at this day) to take the sum of all the characters which the species presented, giving due value and weight to each; and this method has been adhered to in the classification both of the animal and the vegetable kingdom by all our leading naturalists.

The introduction of embryological investigations has furnished an additional and conclusive support in most cases to the results of the exhaustive method of examination already applied to the adult form, seldom aiding us so much in differentiating group from group as in pointing out affinities, and thereby inviting us to throw down boundaries (hitherto scrupulously guarded by the systematic naturalist) and to merge together larger and yet larger groups.

Before this is done, all I would beg is, that the facts and evidences for maintaining the existing arrangement may be carefully reconsidered.

If we are contented to conclude with Dr. Dohrn that "the morphologico-genealogical relations of these three families of Crustacea

("telson"), but is composed of several of the most posterior abdominal segments welded together.

He further confirms my statement, already recorded in my former paper, that the thoracic or opercular plate derives its innervation from a cephalic ganglion, whereas the inner and posterior branchiiferous plates are appendages of the thoracico-abdominal somites.

(viz. Limulida, Eurypterida, and Trilobita) cannot at present be established, perhaps may always remain doubtful," and that we should therefore combine them under one collective name, "*Gigantostraca*," *placing them* "*beside*" the Crustacea, we lay ourselves open to the grave charge of destroying an established system without setting up a new one in its stead.

Take away the Trilobita from the pedigree of the Crustacea, and I submit that one of the main arguments in favour of evolution to be derived from the class, so far from being strengthened, is destroyed. From what are the Crustacea of to-day derived? Are we to assume that they are all descended from the Phyllopods and Ostracods—the only two remaining orders whose life-history is conterminous with that of the Trilobita? Or are we to assume that the Arachnida are the older class?

"If," as Fritz Müller well observes, "all the classes of the Arthropoda (Crustacea, Insecta, Myriopoda, and Arachnida) are indeed all branches of a common stem (and of this there can scarcely be a doubt), it is evident that the water-inhabiting and water-breathing CRUSTACEA must be regarded as the original stem from which the other (terrestrial) classes, with their tracheal respiration, have branched off" * (p. 120).

The accompanying Table will probably express, more strongly than words, my grounds for retaining the Merostomata and the Trilobita also in the Crustacea; but the latter, for the present, distinct from the Xiphosura, although I have no objection whatever to consider them nearly related (ancestrally); and this remark equally conveys my view as to the relationship between the Xiphosura and the Eurypterida, and between the last of these and the Arachnida. But, seeing that there is good evidence of numerous forms of tracheated Arachnida as far back as the Coal-measures, in which there is also evidence of Eurypterida still existing, it seems impossible to pretend that the diverging-point is reached at which the latter cast off its aquatic existence and commenced its terrestrial phase as an Arachnid. *Neolimulus*, again, is a true Limuloid form, and it occurs as far back as *Pterygotus*, or nearly so; and *Hemiaspis* (one of the few intermediate forms met with presenting characters between the long- and the short-bodied divisions of the Merostomata) occurs also in Silurian beds with *Pterygotus* and *Eurypterus*. The Trilobita, from which have branched out the Merostomata, only end in the Carboniferous period; whilst the Isopoda, with which I have ventured to compare them, have been traced back as far as the Devonian.

By placing in a tabular form† the sum of the characters of each order side by side, we are the better able to comprehend the

* 'Facts and Arguments for Darwin,' by Fritz Müller, with additions by the author. Translated from the German, by W. S. Dallas, F.L.S.

† I gave in a table a comparative view of the characters of these four groups in my Report on Fossil Crustacea read before the British Association in Edinburgh, August 1871 (Brit. Assoc. Rep. 1871, p. 53). Noticed in the Geol. Mag. vol. viii. 1871, p. 524.

Recent and Tertiary.	Crustacea. Decapoda. Brachyura.	Crustacea. Decapoda. Macrura.	Stomapoda.	Amphipoda.	Isopoda.	(Trilobita.)	Phyllopoda and Ostracoda.	Merostomata. Xiphosura.	Merostomata. (Eurypterida.)	Arachnida.	Myriopoda.	Insecta.
Cretaceous.					Palæga.		Well represented throughout.					
Jurassic.	Palæinachus.		Squilla.		Archæoniscus.			Limulus.				
Triassic.												
Permian.				Prosoponiscus.								Eugereon, 1 sp.
Carboniferous.		Anthrapalæmon.	Pygocephalus.					Prestwichia. Belinurus.	Eurypterus.	Scorpio, 4 sp. Eophrynus &c., 2 sp. Protolycosa &c., 2 sp.	Xylobius, 1 sp. Euphoberia, 4 sp.	[sp. Coleoptera, 3 Orthoptera, 13 Neuroptera, 14
Devonian.					Præarcturus.				Pterygotus. Stylonurus.			Neuroptera &c., 7 sp.
Silurian.				Necrogammarus.		Trilobita.		Neolimulus. Hemiaspis.	Pterygotus. Slimonia. Eurypterus.			
Cambrian.												

extent to which they are capable of being paralleled; and certainly it seems as if the verdict were in favour of as near a relationship existing between the Isopoda and Trilobita as that which undoubtedly does exist between the Xiphosura and the Eurypterida.

Past progress in palæozoology has been so great, that I am unwilling to conclude with Dr. Dohrn that many points in the genealogy of the Crustacea will probably never be cleared up.

What we seem to need most is, *more workers*, not more fields for palæontological research.

Seldom has a more complete series of remains of any order been met with in a fossil state than those of the *Pterygoti* collected in Lanarkshire; yet these are but the work of one man, Mr. Robert Slimon, of Lesmahagow, from the bed of one small stream, the Logan Water.

The same remark applies to the researches in the Trilobita, carried on by M. Barrande, in Bohemia.

If the Trilobita have already told us so much of their history, may we not yet expect to learn more?

Surely if Mr. Billings's single specimen and that in the British Museum really exhibit legs and a palpus, which there seems no reason to doubt, then others may certainly be looked for and found, and that probably ere long, exhibiting more clearly what is the true organization of this ancient family of the Crustacea.

Discussion.

Prof. T. Rupert Jones remarked upon the high critical value of the paper and on the interest attaching to the study of the Crustacea, and called attention to the apparent absence of any indications of convergence in our present knowledge of the class. He thought that we must nevertheless look back to some point of divergence from which the varied forms known to us may have proceeded by evolution.

Prof. Macdonald remarked that difficulties must be expected to occur in classification. He believed that all Invertebrate animals were to be regarded as turned upon their backs, as compared with Vertebrata. The cephalic plate in *Limulus* he regarded as the equivalent of the palate-bone. The incisive palate was very distinct in the Crabs. The absence of one pair of antennæ did not appear to be any reason for removing *Limulus* from the Crustacea.

Dr. Murie considered that the contemplation of the multitude of young forms referred to by Mr. Woodward should serve as a warning to describers of species, and also as a check to generalizations as to the number of species occurring in various formations. He remarked that if we were at a point when the presence or absence of a single pair of nerves could be taken as distinguishing class from class, these classes must be regarded as very nearly allied. He thought that the doctrine of evolution was being pushed further than the known facts would warrant.

Mr. Woodward, in replying, drew attention to the diagrams of the embryo and larva of the recent *Limulus*, comparing them with *Limulus* of the Coal-measures, *Neolimulus* of the Silurian, and also with the larval stages of the Trilobites discovered by Barrande. He pointed out the strong resemblance which the fossil forms offer to the early stages of the modern King-crab, and expressed his assent to the proposal of Dr. Dohrn to bring the Trilobita, if possible, nearer to the Merostomata. If, however, the Trilobites have true walking-legs instead of mouth-feet (gnathopodites) only, they would be more closely related to the Isopoda. He showed from his tabular view of the Arthropoda that the known range in time of the great classes is nearly the same, and therefore affords no argument for combining the Merostomata with the Arachnida; but, on the contrary, he considered that the Trilobita were, with the Entomostraca, the earliest representatives of the class Crustacea, and therefore could not be removed from that class.

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American Chemist. Vol. ii. Nos. 1 & 2. July and August 1871.

American Journal of Science and Arts. Third Series. Vol. i. Nos. 5 & 6. May and June 1871.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

January 10, 1872.

William Cockburn, Esq., of Upleatham, Yorkshire, and George William Stow, Esq., of Queenstown, South Africa, were elected Fellows, and Dr. Dionys Stur, of Vienna, a Foreign Correspondent of the Society.

The following communications were read:—

1. *On* Cyclostigma, Lepidodendron, *and* Knorria *from* Kiltorkan. By Prof. Oswald Heer, F.M.G.S.

[Printed in the present Number as an Appendix to Professor Heer's postponed paper "On the Carboniferous Flora of Bear Island."]

2. Notes *on the* Geology *of the* Plain *of* Morocco, *and the* Great Atlas. By George Maw, Esq., F.G.S. &c. *With an* Appendix, by R. Etheridge, Esq., F.R.S., F.G.S.

[Plate III.]

Of the geology of Barbary, nothing has heretofore been put on record excepting a few cursory remarks on the Morocco Plain by Dr. Hodgkin, in his account of Sir Moses Montefiore's 'Mission to Morocco in 1864,' and a short paper, by Mr. G. B. Stacey, on the subsidence of the coast near Benghazi, published in the 23rd volume of the Quarterly Journal. Barbary, with the exception of the immediate neighbourhood of a few of the ports, has been almost inaccessible to Europeans; and the extreme jealousy of the Moorish Government with reference to the mineral riches of the country has hitherto prevented any geological investigation.

During the spring of the present year I had the advantage of accompanying Dr. Hooker to Morocco and the Great Atlas, permission for our visit having been obtained from the Sultan through representations made to the Moorish Government by Lord Granville through Sir John D. Hay, our Ambassador at Tangier.

The object of the journey was mainly botanical; and as an engagement was given by Dr. Hooker that we should not collect minerals, the opportunities for geological investigation were very limited.

The observations I was able to make on the structure of the great chain, which had not been previously ascended by a European, and of the Plain of Morocco, are embodied in the accompanying section (Pl. III. fig 1). Stopping for about a fortnight at Tangier, we made several excursions in the neighbourhood. The western part of the northern promontory of Morocco, facing the Straits of Gibraltar, consists of highly contorted beds of hard courses interstratified with brindled yellowish sandstones and variegated puce and grey marls, having a general dip to the south-east, but so twisted about that the dip and strike are often reversed within a few feet. The country has a general undulating contour, here and there rising up into ridges of from 2000 to 3000 feet, in which the hard bands weathered out from the softer strata are strikingly prominent from a great distance.

There is no palæontological evidence of their age; but, judging from their resemblance to the cliff-sections near Saffe, in which fossils occur, they are presumably Neocomian or Cretaceous.

The eastern half of the northern promontory, including Tetuan and Ape's Hill, facing Gibraltar, consists of beds of a different character, for the most part of a hard metamorphic limestone in which dip and strike are very obscure: these may be a southern extension of the Gibraltar limestone; but I had no opportunity of tracing the connexion to Tetuan.

The Tetuan limestone has given rise to enormous beds of brecciated tufa, on terraces of which the city is built. The flow seems to have taken place from the hills to the north-west of the city, and has produced beds of a collective thickness of 60 or 70 feet. This is evidently true tufa, due to aqueous deposition, and is of a different character from the great calcareous sheet, to which I shall have occasion further to refer, which shrouds over the entire plain of Morocco.

Respecting the Mediterranean coast-line of Barbary, I will not add much to a paper read before the British Association at Liverpool, in which I remarked on the singular absence of coast-cliffs of any height. The undulating contour of the land-surface extends down to the water's edge in continuity with the form of the bottom of the straits without the intervention of cliff-escarpments, from which I surmised that the present sea-level and coast-line of the straits had not been of long duration.

Of frequent changes of level on the Barbary coast there is abundant evidence. The more recent seem to be, first, an elevation of from 60 to 70 feet along the entire coast, implied by the existence of concrete sand-cliffs with recent shells exactly similar to the raised beaches of Devon and Cornwall. These occur in Tangier Bay to a height of 40 feet, resting on the upturned edges of nearly vertical mesozoic beds, to the south of Cape Spartel, as a long cliff nearly 50 feet high, as low shoals near Casa Blanca, as a compact cliff about 50 feet high at Saffe, and as a coast cliff and islands at Mogador, where the concrete sand-beds attain a height of 60 or 70 feet above the sea-level. It seems probable that this elevation of coast-line was coincident with a similar rise, implied by the existence of concrete sand-cliffs, all along the Spanish and Portuguese coasts, viz.:—on the eastern face of Gibraltar, where stratified raised beaches are seen cropping up at a considerable height from under the great mass of drift-sand in Catalan Bay; at Cadiz, as low cliffs 40 to 50 feet high, forming a hard coarse freestone of which the city is built; and also at the Rock of Lisbon, where, at a height of from 150 to 180 feet, isolated fragments of stratified concrete sandstone are seen clinging to the sea-escarpment of the older rocks.

The great range of latitude included in this simultaneous coast-rise, suggests the probability that the elevation of similar coast-beds in Devon and Cornwall may pertain to the same movement.

Judging from the evidence afforded by the coast near Mogador, a subsequent submergence appears to be taking place. The island forming a breakwater to the harbour, which is now separated by a channel 27 feet deep, was, within the memory of the last generation, connected with the mainland at low water, so that cattle could be driven across: formerly steamers had to round the island, but now pass into the harbour between the island and the town. The island is sensibly diminishing in bulk; and, from observations made by M. Beaumier, the French Consul, its area has been reduced one-fourth in 20 years; but whether from denudation or subsidence is not clear, though the formation of a channel 27 feet deep cannot possibly in such a position have been due to submarine denudation. The sea is moreover sensibly encroaching, as an old Portuguese Fort and some Moorish buildings are now environed with sand and salt-marsh close to the sea, in a position where they would not have been built. This submergence of the coast at Mogador may perhaps be contemporaneous with the subsidence at Benghazi, Barbary, described by Mr. G. B. Stacey in the twenty-third volume of the Quarterly Journal. The general absence of cliffs characterizes nearly the whole of the Barbary coast. A few low cliffs occur at scattered intervals west of Tangier; but from Cape Spartel to Cape Cantin a low monotonous coast shelves under the waters of the Atlantic, and not a cliff is to be seen, save an occasional raised beach. After rounding Cape Cantin the coast trends nearly north and south; and here the first good coast-section presents itself as a vertical cliff nearly 200 feet high (Pl. III. fig. 2), consisting of nearly level stratified alternations of grey and reddish marl, and fine-grained sandstone with beds of argillaceous carbonate of iron resembling the cement-stone of the Kimmeridge clay.

At a distance the cliff has a massive rocky aspect due to the vertical infiltration of tufaceous seams, which support the softer beds and stand out in prominent masses. The cliffs continue southwards to Saffe, where I obtained a small series of fossils from the section represented in fig. 2, amongst which Mr. Etheridge has determined *Exogyra conica*, *Ostrea Leymerii*, and *O. Boussingaulti*. He considers the beds to be of Neocomian age. The hard band C is almost entirely made up of *Exogyra conica*.

Two or three miles south of Saffe another section occurs, known as the "Jew's Cliff;" and from this Dr. Hooker, who landed on his homeward voyage, obtained a few fossils, viz.:—several undeterminable species of *Pecten*; an *Ostrea* allied to *O. Virleti*; and a scutelliform *Echinus* of an unknown type, which Mr. Etheridge proposes to place under a new genus, and names *Rotuloidea fimbriata* *. All these Mr. Etheridge supposes to be of Miocene age; and the "Jew's Cliff" section may probably give the key to the age of the beds of the Morocco plain in which we found no fossils.

I am indebted to Mr. Carstensen, H.B.M. Viceconsul at Mogador, for a specimen of *Ostrea Leymerii*, brought to him by a Moor from Agader, and obtained, at a height of 1500 feet, on the flanks of the maritime termination of the Great Atlas range, 160 miles south of the Saffe section.

The only other point in the geology of the coast-line I have to refer to is, the great mass of blown sand surrounding Mogador, presenting a weird expanse of sea-like waves of sand, on a scale vastly greater than any thing of the kind on our own coast, mimetic of mountain-chains and bold escarpments in miniature, differing only from true hill-and-valley structure in the absence of continuous valley-lines, the hollows being completely surrounded by higher ground. Many of the ranges of sand are from 80 to 100 feet in height; and their perfectly straight scarped faces are produced by the violent westerly gales blowing the sand *up* the angle of repose, and accumulating it in fountain-like showers over the rounded backs of the sand-hill ranges.

It is worthy of note that the subaerial ripple-markings superimposed on the greater undulations, occupy a reversed position with reference to the prevalent winds, their long side facing the wind, with the more vertical straight scarps on the lee side. The moving sand in this case is drifted up the long side and falls over the scarp at the angle of repose.

The Plain of Morocco.—We now turn inland; and before referring to the details of the structure of the Great Atlas range, it will save repetition if I briefly describe the general contour of the district under consideration. Leaving the sand-hills, which die out inland, we gradually ascend over an undulating country, in aspect somewhat like the weald of Sussex, covered for 30 miles with Argan Forest, till we reach, at 60 miles inland, the average level of the plain, about 1700 feet above the sea.

The fundamental rock is here rarely to be seen; for the entire face of the country is shrouded over by a sheet-like covering of tufaceous crust (Pl. III. figs. 3 & 4), rising over hill and valley and following all the undulations of the ground. Only in river-beds and here and there by the side of a hill were the fundamental beds visible, and seen

* See Appendix, p. 97.

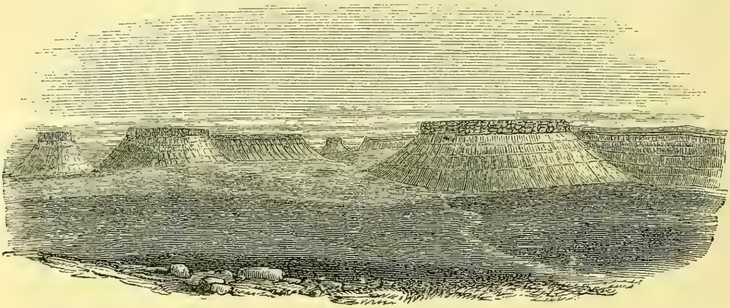
to consist of alternations of hard and soft cream-coloured calcareous strata dipping and undulating in various directions at low angles, and so closely resembling the surface-crust that it was difficult to distinguish the one from the other, unless the surface-crust happened to lap unconformably over the scarped exposures of the stratified beds. This singular deposit varies in thickness from a few inches to two or three feet, and is taken advantage of by the Moors for the excavation of cellars in the soft ground, over which the crust forms a strong roof. These are termed *matamoras*, and are used for the storage of grain, and as receptacles for burying the refuse from the villages. The calcareous crust in the neighbourhood of Morocco is extensively burned for lime. In section it presents a banded agatescent structure, often much brecciated. It is impossible it can have been deposited by any waterflow, as completely isolated hills are shrouded over by it as thickly as the valley-bottoms; and the only satisfactory explanation of its origin I can suggest is, that it results from the intense heat of the sun rapidly drawing up water charged with soluble carbonate of lime from the calcareous strata, and drying it, layer by layer, on the surface, till an accumulation several feet thick has been produced. The rapid alternation of heavy rains and scorching heat which take place in the Morocco Plain are conditions favourable to this phenomenon, which is unknown in temperate climates.

A familiar illustration of the same kind of action is seen in what brickmakers term “limewash.” A brick formed of marl containing soluble carbonate of lime, if rapidly dried or placed in the clamp in a wet state, will have on its upper surface, after burning, an unsightly white scum or crust, by the accretion of soluble matter driven upwards and outwards by the quick evaporation. Before we left Mogador on our journey inland, we were told of great beds of shingle covering the plain, and fully anticipated some interesting drift-phenomena; but these shingle-beds were found to be nothing more than the broken débris of the surface-tufa, covering the plain for hundreds of square miles with stony fragments. Of marine drift there is not a vestige, the few isolated patches of waterworn stones and alluvial shingle being always connected with river-valleys, excepting only the huge boulder-deposits of the Atlas hereafter to be referred to.

About midway between Mogador and the city of Morocco the monotony of the plain is broken by a curious group of flat-topped hills (woodcut, fig. 1), which rise two or three hundred feet above its general surface. They present straight scarped sides, on which are exposed cream-coloured calcareous strata capped with a flat tabular layer of chalcedony, which seems, in arresting denudation, to have determined their peculiar and symmetrical form. In these we found no fossils; and I am doubtful whether they are an inland extension of the Miocene beds observed by Dr. Hooker at the “Jew’s Cliff,” near Saffe, or are some members of the Cretaceous series, of which there are sections on the coast north of Saffe and on the flanks of the Atlas.

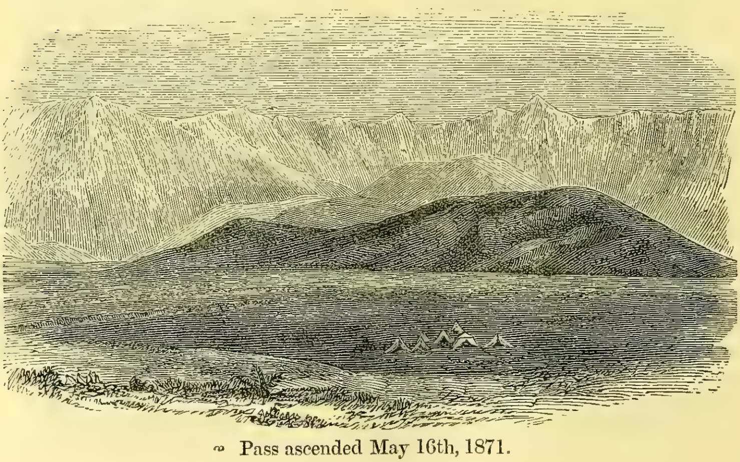
At this point the main boundaries of the plain come into full view,—on the north a rugged range of mountains trending east and west, which we estimated at from 2000 to 3000 feet in height; and on our right the great chain of the Atlas, rising 11,000 feet above us and between 12,000 and 13,000 feet above the sea, bounds the southern horizon, framing-in the great plain, here some 50 miles broad, which is lost as a level horizon in the eastern distance.

Fig. 1.—"*Camel's Back,*" *flat-topped hills in the plain of Morocco.*



The Atlas Range.—Commencing at Cape Guer, on the Atlantic sea-board, the range, which at a little distance has the aspect of a single ridge, averages at its western extremity from 4000 to 5000 feet in height, from which it slightly falls off in height eastwards; it then rises again in the province of Haha to a maximum height of 11,500 feet at a point, Djeb Tezah, 100 miles from the coast, and about S.W. of the city of Morocco. Here a second depression occurs, affording a pass to the south, at an altitude of about 7000 feet; and immediately east of this, and due south of the city of Morocco, the range for 30 miles in length presents a long unbroken ridge, 12,000

Fig. 2.—*Ridge of the Great Atlas, due south of Morocco,* 12,000 *to* 13,000 *feet, as seen from Sectana, Atlas plateau,* 4500 *feet.*



∾ Pass ascended May 16th, 1871.

feet in height, on which are disposed a few isolated crags and peaks rising from 500 to 800 feet above the general level; and it is doubtful whether any part of the chain attains an extreme height of 13,000 feet (fig. 2). Still further east the ridge-like character is lost, the range becoming broken up into a series of less-continuous peaks (including Miltsin) of diminished height: beyond this, eastward, little or nothing is known either of the altitude or character of the range, excepting that it trends N.E. by E. towards the southern borders of Algeria on the Sahara.

Rolfe, in his journal of his overland journey from Morocco to Tunis, speaks of mountains to the east of Morocco being covered with *perpetual* snow; but this is a character which has been erroneously attributed to the Moroccan section of the Atlas range. When we arrived at Morocco in the first week of May, the snow was limited to steep gullies and drifts—all the exposed parts, including the very summit, being entirely bare. There were, however, frequent storms, which intermittently covered the range down to 7000 or 8000 feet; but it is certain that these occasional falls would be rapidly cleared off by the summer heat; and we came to the conclusion that there was nothing like perpetual snow on any portion of the chain we visited, included in the section (apparently the highest part) lying due south of the city of Morocco.

As seen from the city, the great ridge appears to rise abruptly from the plain some 25 miles off; and so deceptive is the distance, that it looks as though it was a direct ascent from the plain to the snow-capped summit, even too steep to scale; but in reality this wall-like ridge represents a horizontal distance of 15 miles from the foot to the summit. As we approached it, an irregular plateau four or five miles wide was seen to form a sort of foreground to the great mass of the chain, from 2000 to 3000 feet above the plain, and 4000 to 5000 feet above the sea-level. This is intersected by occasional narrow ravines, which wind up to the crest of the ridge; and its face, fronting the plain, is for the most part exposed as an escarpment of red sandstone and limestone beds dipping away from the plain, and again rising from a synclinal against the crystalline porphyrites of the centre of the ridge, and unconformably overlying nearly vertical grey shaly beds with a strike ranging with the general trend of the Atlas range. Against the plateau-escarpment rest enormous mounds of boulders spreading down to the level plain.

These, then, are the general features of the chain of the Atlas and plain of Morocco, the further details of which it will be convenient to consider under the following heads:—

(*a*) Surface-deposits and Boulder-beds.
(*b*) Moraines of the higher valleys.
(*c*) Stratified Red-Sandstone and Limestone Series.
(*d*) Grey Shales.
(*e*) Metamorphic Rocks.
(*f*) Porphyrites.
(*g*) Eruptive Basalts.

(a) *Surface-deposits and Boulder-beds.*—Next to the Tufa-crust already described, which extends over almost the entire plain of Morocco, perhaps the most remarkable feature in the physical geology of the country is the enormous deposit of boulders that occurs in the lateral valleys and flanks the great chain on its confines with the plain. Of marine drift there is not a trace; and alluvial drift and valley-gravels are very limited in their distribution, being confined to the borders of a few insignificant rivers that intersect the plain and the localities of occasional waterflows; but as soon as the flanks of the Atlas are reached, new and distinct drift-phenomena present themselves. It was on our second day's journey from Morocco to the Atlas that the great boulder-beds came under our notice, first in a valley leading up from Mesfeua to Tassemarout, as scattered blocks of Red Sandstone, remarkable for their large average size, many of them of from ten to twenty cubic yards; but here the method of their disposition scarcely enabled us to decide that they were other than stream-borne masses from the higher ground. From Tassemarout we turned west, and at the mouth of a second valley, two miles from the village, suddenly came upon a huge development of these Red Sandstone boulder-beds as great ridge-like and very symmetrical masses with terminal faces three or four hundred feet high, and, like the more scattered blocks N.W. of Tassemarout, intermixed with but a very small proportion of fine matter. From this valley we turned out northwards, skirting the escarpment facing the plain; and for more than ten miles no lateral valley breaks into the cliff-like face; but below it the great boulder-beds (Pl. III. figs. 5, 6) still occur in huge masses not resting directly against the escarpment, but as isolated mounds two or three hundred feet in advance, sloping down towards the escarpment in one direction, and in the other rolling away in great wave-like ridges and undulating sheets, which terminate at a well-marked line of demarcation, just where the level portion of the plain commences. I measured by aneroid the height of these mounds; and at one point their summit was 3950 feet above the sea-level, from which they spread down uninterruptedly to the edge of the plain nearly 2000 feet below. They bear a striking resemblance to the glacial ridges or escars between Edinburgh and Perth; their mound-like structure is distinctly visible from the city of Morocco, 25 miles off, appearing like a row of pyramidal tali resting against the face of the escarpment as though they had been cast down from its edge on to the plain. The internal structure of the mounds also suggests such a deviation from the disposition of the boulders in layers sloping away from the escarpment towards the plain; and on a nearer approach it is seen that the individual mounds are not connected with channels or valleys breaking through the escarpment.

The depression between the escarpment and the drift-mounds is a remarkable feature, and suggests an entire change of conditions since the boulder-beds were deposited. If they are a mere subaerial talus, they should rest directly against the cliff face, and the valley of separation must have been formed after the accumulation had ceased; and yet no satisfactory reason can be assigned for such cessation, if rain and river-action were the only operating causes.

The form of the mounds in the valley west of Tassemarout at once conveyed to me the impression that they were of glacial origin; and the discovery of undoubted moraines in the higher valleys strengthened my conviction that the Boulder-mounds and ridges flanking the Atlas plateau can only be satisfactorily explained as the result of glaciers covering the escarpment, leaving on their recession the intermediate depression.

(b) *Moraines of the higher Atlas.*—Kindred phenomena occur higher up in the Atlas valleys, most notable in the case of unquestionable moraines, commencing at the village of Eitmasan in the province of Reria, at an altitude of 6000 feet. Here we met with a gigantic ridge of porphyry blocks, having a terminal angle of repose of between 800 and 900 feet in vertical height, and grouped with several other mounds and ridges of similar scale, all composed of great masses of rock with little or no admixture of small fragments, and completely damming up the steep ravine and retaining behind it a small alluvial plain 6700 feet above the sea-level.

We failed to detect any scratched blocks or striæ; but that these ridges are true glacial moraines no one who has seen them and compared them with other glacial phenomena, would for a moment doubt; and their interrupted occurrence at various heights is strictly in accordance with the distribution of moraines in many of the Swiss and Scotch valleys.

(c) *Stratified Red-Sandstone and Limestone Series.*—A long line of comparatively low and flattish hills, forming a plateau, with an average height of about 4500 feet above the sea, and 2800 feet above the plain of Morocco, intervenes between it and the main ridge of the Atlas. The edge of this plateau facing the plain is for some distance an escarpment, exposing stratified beds of limestone containing bands of chalcedonic concretions, underlain by grey and puce-coloured marls. As this plateau is crossed from north to south toward the Atlas ridge, its central line would represent a synclinal, from which the beds rise northwards towards the plain and southwards towards the Atlas; but it is locally broken and contorted, and near Tassemarout the limestone beds stand up nearly on end. South of the synclinal, *i. e.* between the centre of the irregular plateau and the Atlas, great deposits of Red Sandstone and dark-red conglomerate, interstratified with cream-coloured shelly limestone, occur, which appear to be inferior members of the same series as the limestone and marls exposed in the escarpment facing the plain. From the few obscure fossils, including an *Ostrea,* I was able to collect from the limestone bands, Mr. Etheridge considers that they are of Cretaceous age. They are, like the beds of the plain, remarkable for containing great deposits of chalcedonic concretions; but the latter may possibly be of more recent age. They rest unconformably on the upturned edges of grey shaly beds, and extend also over the porphyries that form the great mass of the Atlas chain. They appear to have been deposited subsequently to the porphyry-ridge assuming its present hill-and-valley contour, as little isolated fragments are seen clinging to the sides of a narrow ravine leading out of the valley we ascended through the province of Reria to the Atlas. Their relation to the few exposures of stratified beds in the plain is somewhat uncertain, as no fossils were obtained in the latter, and there are no direct connecting links; but, judging from petrological similarity, and from the fact that Neocomian fossils occur in exposed beds on the coast-cliffs, and Cretaceous fossils in the beds forming the crest of the plateau, it seems possible that an unbroken series occurs from the cliff north of Saffe to the plateau skirting the Atlas, representing the whole of the Cretaceous epoch; but it is also open to question whether the level beds of the plain may not be an inland extension of the strata of Miocene age from which Dr. Hooker obtained fossils at the Jew's Cliff south of Saffe.

(d) *Grey Shales.*—At several points on entering the lateral valleys of the Atlas, almost vertical shaly beds are crossed, having a strike nearly east and west, corresponding with the trend of the chain. They clearly underlie, and are unconformable to, the Red-Sandstone and Limestone series; and their almost vertical position appears connected with one of the several upheavals that have affected the chain. Of their geological age there is no evidence, except that they are pre-Cretaceous. In places, as at Assghin, they abound in nodules of carbonate of iron. Pale shales, containing quartz veins, crop up near the village of Frouga, in the plain south-west of Morocco, which may possibly belong to this series; and if the porphyries forming the mass of the Atlas are contemporaneous, they are probably interbedded with these grey shaly beds.

(e) *Metamorphic Rocks.*—The most important development of metamorphic rocks in the neighbourhood of Morocco is on the north side of the city. In its immediate neighbourhood, three miles to the north-west, a low rugged hill occurs, composed of a very hard and compact dark-grey rock, containing knotted white concretions elongated in the line of stratification, which dips from 50° to 80° south-west, the strike being north-west and south-east. The whole of the north side of the plain is bounded by ranges of rugged hills of similar form, and apparently rising from 2000 to 3000 feet above the plain. We had not an opportunity of visiting them; but, judging from their outline, they are identical in formation with the hill close to Morocco. We observed nothing in the Atlas resembling it.

The only other metamorphic rocks that came under our notice were:—first, white marble or metamorphic limestone, intercalated with the porphyrites at the summit of the ridge of the Atlas south of Arroond; secondly, mica-schists, pierced by red porphyry dykes, forming the mass of Djeb Tezah, a point 11,500 feet in height, and 15 miles further west, ascended by Dr. Hooker and Mr. Ball after my return. It is possible that the mica-schists may be a portion of the grey-shale series, metamorphosed by the intrusion of the porphyry dykes.

(f) *Porphyrites.*—Of the eruptive rocks of the Atlas, porphyrites and porphyritic tuffs occupy by far the most prominent position, forming the great mass of its ridge.

On entering the lateral valleys, after crossing the vertical shaly beds, great masses of red porphyrites and tuffs are met with, associated with specular iron and occasional green porphyries. The harder portions of the latter are seen as *Verde antique* pebbles in the river-beds ; but we failed to detect this *in situ*. From the large proportion of tuffs that occurs the porphyrites appear to be interbedded, and are possibly contemporaneous with the vertical grey shales to which they are adjacent. They are overlapped unconformably by the Red-Sandstone and Limestone series of Cretaceous age. Mr. D. Forbes informs me that they bear a strong likeness to the porphyrites of the Andes, of Oolitic age; but beyond the fact that they were in existence and had undergone denudation into hill-and-valley contour before the Cretaceous beds were deposited over them, there is no certain evidence as to their age.

There have been at least one or two subsequent intrusions of red porphyrites, viz. of the dykes of Djeb Tezah, metamorphosing grey shales into mica-schists, and of the dykes that break up through the stratified beds of the plain east of Sheshawa—which are clearly more recent than the porphyrites of the Atlas, as they penetrate strata which extend over the denuded surface of the Atlas mass.

(g) *Eruptive Basalts.*—Of these we met with three distinct species:

(1) Black vesicular basalt (porous and compact pyroxenic lava with olivine) on the coast near Mogador, and imbedded in the base of the post-Tertiary concrete sandstone-cliffs: but it was nowhere seen *in situ* ; and I think it possible that the fragments may have been derived from the Canary Islands, which are only 70 or 80 miles distant, or possibly from some point of eruption nearer the land.

(2) Amygdaloid green Basalt, which rises up in dykes, in many places penetrating the Red-Sandstone and Limestone series on the flanks of the Atlas, and also piercing the diorite of the Arroond valley. We observed numerous dykes at Tassemarout, Tassgirt, and Asni, south-east and south of Morocco city. Beyond the fact that they are probably post-Cretaceous, there is no evidence as to their age. From what we could see of their distribution, the whole range of the Atlas seems abundantly intersected by these dykes.

(3) Diorite rises up in considerable masses among the porphyrites in the valley of Arroond, due south of Morocco, but forms no great proportion of the bulk of the ridge. Its intrusion may have been contemporaneous with the dislocation and upturning of the Red-Sandstone and Limestone series overlying the porphyries.

General Summary.—It now only remains briefly to recapitulate the order of sequence of the geological phenomena observed in the plain of Morocco and the Atlas.

The oldest rocks that have been noticed are:—

(1) The ranges of rugged metamorphic rocks north of the city of Morocco, and forming the northern boundary of the plain, respecting the age of which, and the period of their upheaval and metamorphism, there is no evidence.

(2) The interbedded porphyrites and porphyritic tuffs of the Atlas, forming the backbone of the ridge, the age of which, and of the grey shales with which they seem to be interbedded, is also uncertain.

(3) Mica-schists of Djeb Tezah, in the Atlas, south-west of Morocco, pierced with eruptive porphyritic dykes, which may be an altered condition of the vertical grey shales adjacent to the interbedded porphyrites.

These rocks are our starting-point, respecting which there is no evidence of their age, or even relative age.

(4) We now come to a long period of denudation of the Atlas ridge, and its sculpturing into hill-and-valley contour, before the deposition of the Red-Sandstone and Limestone series.

(5) The deposition, over what is now the Morocco plain, of the Cretaceous Red-Sandstone and Limestone series (and beds possibly of Miocene age), which also occupies preexisting valleys in the older porphyrites of the Atlas.

(6) The intrusion of diorite into the porphyrites and porphyritic tuffs, probably accompanied by a further elevation of the Atlas range, disturbing the stratified Red-Sandstone and Limestone series, throwing them into a synclinal trough, from which the beds rise northwards towards the plain, and southwards towards the Atlas.

(7) A further long period of denudation of the Red-Sandstone and Limestone series, rescooping out the lateral valleys of the Atlas, in continuation of the valleys that existed in the porphyrite ridge prior to their deposition, and also denuding the beds in the Morocco plain to the extent of at least 300 feet, leaving isolated remnants as flat tabular hills rising above the present general level of the plain.

(8) A further emission of red porphyrites through the stratified beds of the plain, which may have been contemporaneous with the eruption of the red-porphyry dykes of Djeb Tezah, in the High Atlas.

(9) A post-Cretaceous eruption through the Red-Sandstone and Limestone series of a multitude of dykes of amygdaloid basalt, the age of which is uncertain.

The more recent changes commence with:—

(10) The formation of gigantic boulder-beds flanking the northern escarpment of the Atlas plateau, and spreading down in great mounds and undulating ridges from a height of 3900 feet to the borders of the plain, 1900 feet above the sea, with a range in vertical height of about 2000 feet, and extending up the entrances of several of the lateral valleys, as well-defined and symmetrical moraines.

(11) The formation of moraines at the heads of the Atlas valleys, commencing at a height of 5800 feet, and spreading up to the cliffs of the Atlas ridge, to a height of between 7000 and 8000 feet, with a terminal angle of repose 850 feet in vertical height.

(12) The formation of a plain of shingle behind the moraines, at a height of about 6700 feet, which seems to be the bed of a small lake.

(13) The recession and extinction of glaciers in the Atlas range, on which there is now not even perpetual snow.

(14) An elevation of the coast-line of at least 70 feet, represented by the height of the raised beaches of concrete sand at Mogador and other parts of the coast, which may possibly be contemporaneous with the elevation of similar raised beaches on the coasts of Spain and Portugal, and with the raised beaches of our south-western coast.

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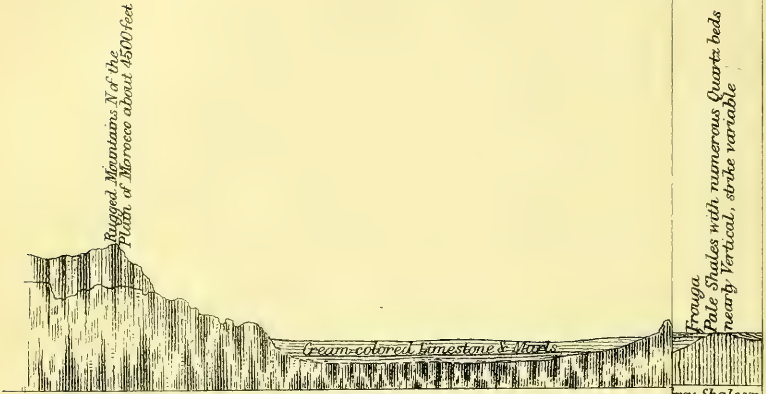
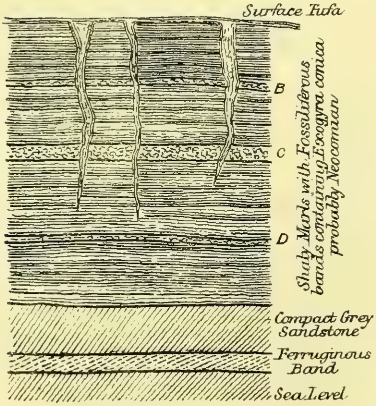


Horizontal Scale one Inch to 3 Miles. Vertical

Fig 2.



CLIFF SECTION, SAFFE.

F. Dangerfield lith 22, Bedford St. Covent Garden.

.Maw delt.

(15) A slight subsidence of the coast-line, now going on, with an accumulation of extensive deposits of blown sand at Mogador.

(16) The formation of a tufaceous surface-crust over almost the entire plain of Morocco, due to the drawing up to the surface, by rapid evaporation, of water from the subjacent calcareous strata, depositing, layer by layer, laminated carbonate of lime.

EXPLANATION OF PLATE III.

Fig. 1. Sketch section across the plain of Morocco to the watershed of the Great Atlas.
2. Cliff-section at Saffe.
3. Section of the Tufa-crust covering the plain of Morocco.
4. Surface of ditto.
5. Section of boulder-mounds skirting the escarpment of the Atlas plateau.
6. Front view of the escarpment and boulder-mounds.

APPENDIX *to* MR. MAW'S PAPER *on the* GEOLOGY *of* MOROCCO, *being a* DESCRIPTION *of a* NEW GENUS *of* FOSSIL SCUTELLOID ECHINODERM *from* SAFFE, N. AFRICA. By R. ETHERIDGE, Esq., F.R.S., F.G.S.

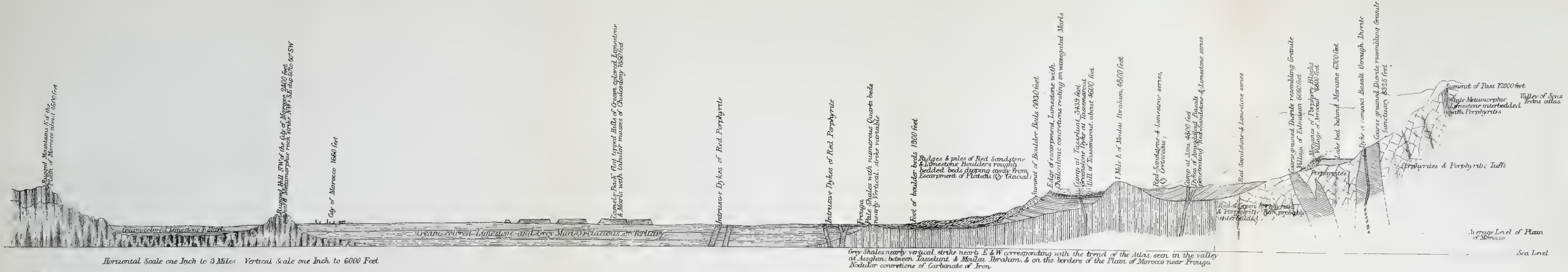
AMONGST the specimens brought by Dr. Hooker and Mr. G. Maw, from Morocco, in North Africa, and submitted to me for examination, were some Urchins of the family *Scutellidæ*, of peculiar form, differing from any I had previously seen or examined, and certainly not referable to any described Tertiary species. Comparison with known forms, recent and fossil, failed to elucidate their true history more than to show that they evidently belonged to the Rotuline group of *Scutellidæ* amongst the Clypeasteroidea, nevertheless differing considerably from the genus *Rotula* (Klein) the only form to which they can be referred.

Rotula now inhabits the sea and coast of Senegal, West Africa, from which two, if not three, species are known:—*R. Rumphii*, Klein; *R. Augusti*, Klein; and *R. Gaulteri*, Ag. There is, however, a marked difference between the characters of our new genus and that of *Rotula*, especially in the more elongated and oval form of the test, the extreme rounding or truncation of the fimbriation, or crenulation, upon the posterior margin, more acute anterior and less tumid lateral margins,—so much so, that a line drawn round the circumference of the test of *Rotula*, including the digitations, would describe a complete circle touching the periphery of the Urchin, whereas the form of *Rotuloidea* is an oval or ellipse—*Rotula* being circular, *Rotuloidea* oval; these, with *other differences* to be hereafter noticed, justify the establishment of a new genus for the reception of these North-African, fossil forms. The resemblance to and affinities with *Rotula* suggest the name *Rotuloidea*.

It is of no small interest thus to obtain from the Great Morocco plain south of Saffe, at "Jew's cliff" &c., what appears to be a less-developed or lower type of Clypeasteroid, which must have been an abundant species in the Miocene sea of that area, then extending far

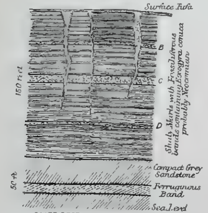
SKETCH SECTION ACROSS PLAIN OF MOROCCO TO WATERSHED OF GREAT ATLAS.

(NOTE. *The "Camels-Back" Hills, & Frouga, are West of the line of Section.*)



Horizontal Scale one Inch to 3 Miles. Vertical Scale one Inch to 6000 Feet.

Fig 2.



CLIFF SECTION, SAFFE.

Fig 3. section.

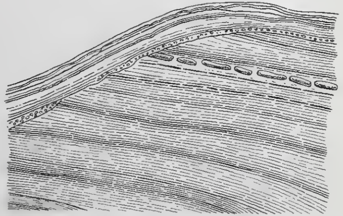
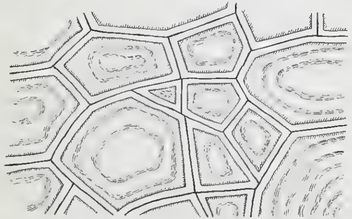
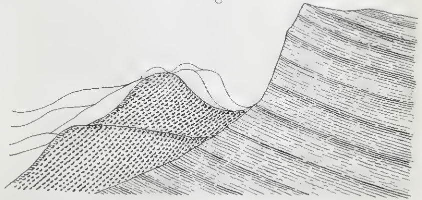


Fig. 4. surface



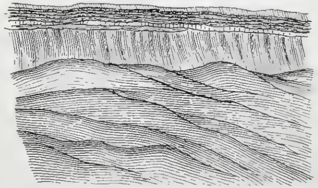
TUFA CRUST COVERING PLAIN OF MOROCCO

Fig 5



BOULDER MOUNDS,
Skirting Atlas Plateau Escarpment
Section.

Fig 6



BOULDER MOUNDS,
Skirting Atlas Plateau Escarpment

F. Dangerfield lith. 22, Bedford St. Covent Garden.

G. Maw delt.

to the north of the habitat or range of its present representative. *Moulinsia*, Ag., which also has some affinity, is now a denizen of the seas around Martinique; this and the extinct genus *Runa* (Ag.) from the Tertiary beds of Bordeaux and Palermo (noticed under the affinities) seem to be, in some respects, allied genera.

This genus is established to receive Scutelloid forms with lobed instead of digitate expansions upon the posterior margin, and otherwise differing from known *Scutellæ*.

Rotuloidea fimbriata, Etheridge.

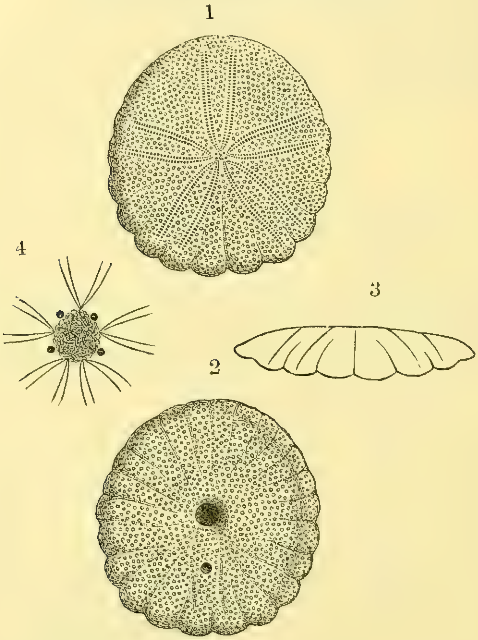


Fig. 1. Dorsal aspect, showing the twelve fimbriations, subpetaloid ambulacra and central madreporic tubercle.
2. Ventral aspect, showing mouth, position of vent, and ramifying furrows.
3. Posterior border and height of test.
4. Apical disk, with the Madreporic tubercle, the four genital pores, and place of the five oculars.

Class ECHINODERMATA.

Order *ECHINIDA*.

Group *Clypeasteroidea*.

Fam. SCUTELLIDÆ.

Genus ROTULOIDEA (Etheridge, 1872).

Gen. char.—General form depressed, broadly ovate, longer than broad; base slightly concave. Dorsal and ventral surfaces densely covered with equal-sized, apparently imperforate, tubercles*. Anterior margin smooth and slightly acute; posterior margin broader than anterior and possessing in the middle six tumid lobes or fimbriations; three others, less tumid, occupy the right and left postero-lateral margins (twelve in all). Ambulacra subpetaloid and equal. Apical disk small, central, round, and covered by the madreporiform plate and tubercle. Mouth central. Vent placed nearly halfway between the mouth and posterior border, nearer the mouth. Tubercles of one order.

ROTULOIDEA FIMBRIATA, sp. nov.

Specific char.—Test thick, elongated, depressed; upper and under surfaces densely and equally covered with small, nearly equal-sized, imperforate tubercles, all of which are surrounded by ring-like areolæ. Base slightly concave and covered by anastomosing, slightly impressed, bifurcating avenues, meeting at the mouth; these carry the "interrupted" pores of the ambulacra. Ambulacra subpetaloid, slightly narrowing on approaching the margin; the right and left postero-lateral pair sharply, or suddenly, diverge on leaving the apical disk, and pass to the margin over two of the posterior crenulations, ceasing to appear in pairs of "hole and slit" about two-thirds down the posterior area. The lateral pair of ambulacra do not diverge so much as the postero-laterals, and occupy, with the odd ambulacrum, the anterior half of the test. The odd or single ambulacrum is straight, occupying the anterior margin. All traces of the pores in the ambulacra are apparently lost at the margin and base, save near the mouth; but on the ventral surface they are represented by five slightly depressed, smooth-looking furrows, possessing numerous small pores; these furrows divide or ramify about halfway between the mouth and margin. The inner row of pores in the poriferous zones are small and round; the outer slit-like, well-developed, and nearly horizontal. Near the margin of the test the subpetaloid condition of the ambulacra ceases, and the pores become unigeminal in single file, a few in scattered pairs passing the margin over definite fimbriations, after leaving which, all direct traces of them are lost amidst the ramifying and anastomosing furrows at the base; but they appear to be trigeminal near the peristome. The posterior and lateral pairs of ambulacra bear peculiar relation to the twelve crenulations occupying the posterior half of the test: four lobes or fimbriations occupy the space between the two extremities of the posterior ambulacra; one branch of each ambulacral zone (consisting of a single pair of pores) passes over the two lobes next the centre pair, thus occupying four and enclosing two. On the lateral margins two lobes occur between the posterior and lateral ambulacra, which latter pass over (also in single file) the two antero-lateral lobes, thus completing the twelve

* In the living *Rotula Rumphii* the puncta of the tubercles are so minute as almost to defy detection microscopically; it would be quite impossible that they could escape destruction under fossilization and mineralization. The term "imperforate," therefore, must be received with this reservation.

fimbriations. The anterior margin is smooth and is occupied by the single ambulacrum. The interambulacral areas are all equal at the margin, owing to the ambulacra being there equidistant.

Apical disk central, small, round, or slightly pentagonal, the whole covered by the madreporic body, which occupies the centre. Ocular plates five, perforated; pores small. Genital plates four, perforated; pores large.

Mouth ventral, lodged in a slight depression in the centre of the base. Peristome subpentagonal, and margin slightly thickened.

Vent subcentral, small, situated between the mouth and posterior border, nearer the former by one third the distance from anal aperture to margin at base of centre fimbriations.

Tubercles all of one order, apparently imperforate, Microscopical investigation failed to detect any puncta; but so delicate must they have been in the living state, that all evidence would be obliterated during the process of fossilization; in the living *Rotula* the tubercular pore is hair-like. The tubercles are surrounded by shallow areolæ, the peripheries of which nearly touch each other; and there are no scattered secondary tubercles as in *Rotula*.

Affinities and differences.—In the gently arcuated form of the dorsal surface, general characters of the ambulacra, as well as in the position of the mouth and anal aperture, *Rotuloidea fimbriata* closely resembles *Rotula Rumphii*, Klein; the test, however, differs considerably in many points from that of any known *Rotula*. *R. Rumphii* is quite circular, including the digitations, which nearly equal one fourth the diameter of the test and are deeply segmented; whereas the form of *Rotuloidea* is oval, broader posteriorly than anteriorly, and the fimbriations on the posterior border are tumid, scarcely projecting beyond the general margin, being little more than mere crenulations; these marginal undulations are faintly traceable up the anal or posterior half of the dorsal surface of the test to near the apical disk, and most pronounced between the right and left postero-lateral ambulacra. A difference, also of chief importance, exists in the arrangement of the poriferous zones in our genus compared with those of *Rotula*: in *Rotula Rumphii* the outer slit-like ambulacral pores are inclined at a greater angle than in *Rotuloidea*, in which they are nearly horizontal; in *R. Gaulteri* and *R. Augusti* also the slits lie at a *considerable* angle. The connecting fissures cannot be traced in *Rotuloidea*, owing to the mineralized condition of the test. The pore-slits cease at one third from the margin. The ambulacra of the living *Rotulæ* are narrower and slightly more petaloid than in *Rotuloidea*; and in this important character the species of *Rotula* differ much from each other, especially as regards the outer zone of elongated pores.

The chief tubercles upon the test of *Rotula* are also much smaller and more closely packed than in *Rotuloidea*; and the living type, *Rotula Rumphii*, possesses secondary tubercles somewhat irregularly placed among the primary ones; none, however, occur upon the test of *Rotuloidea*, all being of one order; again, in *R. Gaulteri* and *R. Augusti* the tubercles are so delicate and close as scarcely to be detected microscopically.

In the slight development of the posterior and lateral fimbriations and in the position of the mouth and vent, *Rotuloidea* has affinity with the Martinican genus *Moulinsia*, Ag.; but the entire margin, as well as the dorsal and ventral surfaces, of *Moulinsia* is crenulated; the elements of the apical disk, also, at once remove it from that genus. The same comparison may apply to the genus *Runa*, Ag., from the Tertiary beds of Bordeaux and Palermo, in whose crenulated or fimbriated margin, as well as the position of the mouth and vent, there is much resemblance to the new form; but the affinity disappears upon comparing the ambulacra of the dorsal surface with those of *Rotuloidea*: both nevertheless belong to one group of Urchins. But for the depression of the test, the position of the anal aperture, the grooved avenues on the base carrying the ambulacra, and the lobed peristome, this genus might almost be referred to *Pygurus* (amongst the *Echinolampidæ*) of the Oolites and Cretaceous rocks of Europe; for the margin of many forms of that genus is broadly and strongly lobed (notably so in *P. Blumenbachii*). Again, the apical disk and dorsal aspect have strong resemblance to those of *Pygurus*, and also of *Clypeus Plottii*; and the wandering ambulacra at the base of *Rotuloidea* give it an affinity to the digitate *Pyguri* of the Oolitic rocks.

The Urchins of this singular group in their recent state seem to be confined to the western coast of Africa, near Senegal; and I believe the specimens brought by Mr. Maw are the first of the true Rotuline type ever found fossil.

Geological position.—In assigning to *Rotuloidea* its horizon in time, I believe it to be Miocene, and an extinct genus; it is associated with Miocene species, and would seem to be the earliest known form of the Rotuline group.

DISCUSSION.

Mr. BALL, as an Alpine traveller who had also visited the Atlas in company with Dr. Hooker and Mr. Maw, offered a few remarks. The plain of Morocco was not, in his opinion, a level, but an inclined plane, rising gradually in height up to the foot of the mountain, so that the base of the boulder ridges was at some height above the level of the plain near Morocco. He did not think that the boulder deposits could be safely attributed to glaciers, but thought rather that they had been carried into and deposited in a shallow sea. He thought also that Mr. Maw had somewhat overestimated the thickness of some of the boulder deposits; and though there was one instance of an undoubted moraine in one of the higher valleys of the Atlas, yet he could not agree in the view that the glaciation of the Atlas was general. He could not accept such a great thickness of beds as that represented by the vertical shales in Mr. Maw's section.

Prof. RAMSAY was pleased that the author, though giving so many interesting details, had not assigned any definite age to many of the beds. He agreed with him as to the cause assigned for the great tufaceous coating of the country. He had already assigned the same cause for the existence of certain saline beds, and would attribute the existence of the great coating of gypsum at a slight depth below the surface of the Sahara to the same cause. As to the existence of moraines, he was not surprised to find them in the Atlas, as they were already known in the mountains of Granada. As to the escarpments, it was now well known that, as a rule, they assumed a direction approximately at right angles to the dip of the strata; and he felt inclined to consider that the bulk of the mounds at the foot of the escarpment of the Atlas were rather the remains of a long series of landslips from the face of the cliffs than due to an accumulation of moraine matter.

Mr. D. Forbes commented on the similarity of the rocks to those of the Andes in South America. In the Andes the porphyritic tuffs appeared to belong to the Oolitic age; and the igneous rocks associated with them were of the same date. He thought that, so far as the author's observations had gone, the structure of the Atlas was much the same as that of the Andes.

Mr. W. W. Smyth mentioned that in the district to the east of the Sierra Nevada, in the south part of Spain, where there was great summer heat, and also heavy occasional rainfall, the same tufaceous coating as that observed in Morocco was to be found. He had been led to much the same conclusion as to its origin as that arrived at by Mr. Maw. The upper part was frequently brecciated, and the fragments recemented by carbonate of lime.

Mr. Seeley, though accepting Mr. Etheridge's determination as to the Cretaceous age of the fossils if found in England, could not accept it as conclusive in the case of fossils from Morocco. The genus *Exogyra*, for instance, which ranges through the secondary and up to existing seas, might well belong to some other age; and even the fossils presumably Miocene might, after all, date from some other period.

Mr. Maw, in reply, stated that he agreed with Mr. Ball as to the rise in the Morocco plain as it approached the Atlas, and pointed out that his section actually represented a rise of 400 feet from the city of Morocco to the foot of the boulder mounds; but in addition to this gradual rise there was a range of altitude of 2000 feet from the foot to the summit of the boulder beds.

He also pointed out the resemblance between the interrupted occurrence of the boulder mounds in the Atlas and the distribution of glacial moraines in the Rhone valley, and in the valley of the Esk, in Forfarshire. As a proof that the boulder mounds on the flanks of the Atlas consisted of transported blocks, he mentioned the fact that the red sandstone rock of which they were composed did not occur in the adjacent escarpments, and was not to be found within four or five miles. There was, moreover, a mixture of different materials in the mounds.

January 24, 1872.

Henry Ludlam, Esq., of 174, Piccadilly, W., and Charles Whitehead, Esq., J.P., F.L.S., F.S.A., of Barming House, Maidstone, were elected Fellows of the Society.

The following communications were read:—

1. *On the* FORAMINIFERA *of the* FAMILY ROTALINÆ (*Carpenter*) *found in the* CRETACEOUS FORMATIONS; *with* NOTES *on their* TERTIARY *and* RECENT REPRESENTATIVES. By Professor T. RUPERT JONES, F.G.S., and W. KITCHEN PARKER, Esq., F.R.S.

CONTENTS.

§ I.—IN preparing lately some critical notes* on the Foraminifera from the Chalk of Gravesend and Meudon, figured in Dr. Ch. G. Ehrenberg's 'Mikrogeologie' (1854), we were much impressed with the desirability of pointing out as clearly as we could the specific relationship of those members of the "Rotaline" family of Foraminifera which have been found in the Chalk and associated strata, and have been figured and described by various palæontologists. This seemed the more requisite, inasmuch as these Foraminifera are mostly disguised by an old-fashioned and incorrect nomenclature. The relationship, also, of the Cretaceous to the Tertiary and Recent *Rotalinæ* seemed to require elucidation.

* Published in the 'Geol. Mag.' Nos. 89 & 90, Nov. and Dec. 1871.

§ II.—Without further preface, we proceed to notice that among Ehrenberg's figures (i.) from Meudon, near Paris ('Geol. Mag.' vol. viii. pp. 511 & 563), we recognize only:—

1. Planorbulina ammonoides (*Rss.*).
2. —— globulosa (*Ehr.*).
3. Pulvinulina truncatulinoides (*D'O.*).
4. —— Micheliniana (*D'O.*).

(ii.) From Gravesend:—

1. Planorbulina ammonoides (*Rss.*).
2. Pulvinulina Micheliniana (*D'O.*).

§ III.—From Meudon, Sens, and St. Germains, near Paris, M. d'Orbigny had already obtained (in 1840*):—

1. Planorbulina Voltziana (*D'O.*).
2. —— Lorneiana (*D'O.*).
3. —— Clementiana (*D'O.*).
4. —— (subgen. Truncatulina) Beaumontiana (*D'O.*).
5. Pulvinulina Micheliniana (*D'O.*).
6. —— crassa (*D'O.*).
7. —— Cordieriana (*D'O.*).
8. Rotalia umbilicata (*D'O.*).

All of these M. d'Orbigny found also in the English Chalk.

§ IV.—In our own Collection we have:—

1. *From the Chalk (Upper) of Thorpe, near Norwich.*

1. Planorbulina Haidingerii (*D'O.*).
2. —— Ungeriana (*D'O.*).
3. —— ammonoides (*Rss.*).
4. —— (Truncatulina) lobatula (*W. & J.*).
5. Rotalia umbilicata (*D'O.*).
6. Tinoporus concavus (*Lamk.*) *et* globularis (*Phil.*).

2. *From the Chalk of Gravesend.*

1. Planorbulina Ungeriana (*D'O.*).
2. —— ammonoides (*Rss.*).
3. —— (Planulina) ariminensis (*D'O.*).
4. —— (Truncatulina) lobatula (*W. & J.*).
5. Pulvinulina Micheliniana (*D'O.*).
6. Rotalia umbilicata (*D'O.*).
7. Tinoporus concavus (*Lamk.*) *et* globularis (*Phil.*).

3. *From the Chalk-marl of Kent*†.

1. Planorbulina Ungeriana (*D'O.*).
2. —— ammonoides (*Rss.*).
3. Pulvinulina Menardii (*D'O.*).
4. Tinoporus concavus (*Lamarck*) *et* globularis (*Phil.*).

4. *From the Gault of Kent.*

1. Planorbulina Ungeriana (*D'O.*).
2. —— ammonoides (*Rss.*).
5. Pl. (Truncat.) variabilis (*D'O.*).
4. Pulvinulina caracolla (*Rœm.*).

5. *From the Gault of Biggleswade, Bedfordshire.*

1. Planorbulina ammonoides (*Rss.*).
2. —— (Truncat.) lobatula (*W. & J.*).
3. Rotalia umbilicata (*D'O.*).

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* Mém. Soc. Géol. France, vol. iv. part 1.

† Partly from Dover, but mostly from Charing, collected by W. Harris, Esq., F.G.S.

6. *From the Greensand of Warminster.*

1. Planorbulina Ungeriana (*D'O.*).
2. —— ammonoides (*Rss.*).
3. —— (Trunc.) lobatula (*W. & J.*).
4. Pulvinulina caracolla (*Rœm.*).
5. Tinoporus concavus ? (*Lamk.*)*.
6. Patellina lenticularis (*Blumenbach*).

Of these there are also subvarieties corresponding more or less closely not only with those named by M. d'Orbigny †, but also with many of the numerous Rotaline varieties recorded by Prof. Reuss and others from the Chalk of Europe. This will appear more distinctly in the promised Monograph on the British Cretaceous Foraminifera by ourselves and Mr. H. B. Brady. Thus, although wonderfully constant in chief characters, the little *Planorbulina ammonoides* is linked by slightly divergent subvarieties with *Pl. (Planulina) ariminensis* on the one hand, and with *Pl. Ungeriana* on the other; and the latter is but a feeble form of *Pl. Haidingerii*, and so on. So also the small forms of *Planorbulina* figured by D'Orbigny from the Chalk of France may be said to radiate from *Pl. ammonoides* with gentle modifications.

§ V.—Among Dr. Ehrenberg's figures of Foraminifera from (1) the Chalk of Möen, Denmark ('Mikrogeol.' pl. 14), we find :—

1. Planorbulina ammonoides (*Rss.*).
2. —— globulosa (*Ehr.*).
3. —— (Planulina) ariminensis (*D'O.*).
4. Pulvinulina elegans ? (*D'O.*).
5. —— Orbignyi ? (*Rœm.*).
6. —— spatiosa (*Ehr.*).

(2.) From the Chalk of Rügen, in the Baltic, Ehrenberg figures ('Mikrogeol.' pl. 15) :—

1. Planorbulina Haidingerii (*D'O.*).
2. —— ammonoides (*Rss.*).
3. —— globulosa (*Ehr.*).
4. Pulvinulina Micheliniana (*D'O.*).
5. —— squama (*Ehr.*).

(3.) From the Russian Chalk of Volsk ('Mikrogeol.' pl. 16) :—

1. Planorbulina Haidingerii (*D'O.*).
2. —— (Planulina) ariminensis (*D'O.*).
3. Pulvinulina caracolla (*Rœm.*).

(4.) From the North-American Chalk of Missouri ('Mikrogeol.' pl. 17, i.) :—

1. Pulvinulina caracolla (*Rœm.*).

(5.) From that of Mississippi ('Mikrogeol.' pl. 17, ii.) :—

1. Planorbulina ammonoides (*Rss.*).
2. Planorbulina (Planul.) ariminensis (*D'O.*).

In these determinations from Ehrenberg's plates we cannot aim at catching the subvarietal minutiæ very clearly; for the figures are

* This species and its var. *globularis* (Phil.) of the Chalk-marl and Chalk are usually termed *Orbitolinæ*; but they belong to the Rotaline genus *Tinoporus* (see Carpenter's 'Introd. Foram.' pp. 223 &c.). The very similar specimens, however, from the Greensand of Haldon and Milberdown, Devonshire, and some of those from Warminster, are *Patellinæ*, also of the Rotalinæ family.

† Prof. Morris's 'Catalogue of British Fossils,' 2nd edit. 1854.

little more than sections, the object being seen by transmitted light. *Planorbulina globulosa* (Ehr.), must not be regarded as worth much, being a very minute Rotaline, and such a form as several species might present in their earliest stage of growth.

§ VI.—For the recorded Cretaceous ROTALINÆ (Carpenter), besides those of England, France, the Baltic, Russia, and North America already noticed, the most convenient plan will be to simply enumerate them in their groups of alliance, and according to the authors describing them. Thus :—

1. F. A. RŒMER. 'Versteinerungen des Norddeutschen Kreidegebirges,' 1840–41 ; Rhizopoden, pp. 95–99. (Lower Cretaceous.)

1. Pl. 15. fig. 23. Truncatulina lævigata. *Tr. lobatula* (W. & J.).
2. 22. Gyroidina caracolla.
3. 24. Planulina Orbignyi.
4. 25. —— ornata.
} *Pulvinulinæ* near *P. elegans* (D'O.), a subtype of *P. repanda* (F. & M.).
5. 20. Rotalia sulcata. *Planorbulina* (*Truncatulina*) near *Tr. advena* (D'O.).
6. 21. —— conica. *Planorbulina*? Near *Pl. rosea* (D'O.)?

2. FR. VON HAGENOW. 'Monographie der Rügen'schen Kreide-Versteinerungen ;' iii. Abtheilung,—Mollusken. In *N. Jahrb. für Min. &c.* 1842, pp. 528–575.

1. Not figured. Rotalia constricta. Figured by Reuss, 'Sitzungsb. Ak. Wien,' xliv. pl. 6. f. 7, pl. 7. f. 1. Very near *Planorbulina ammonoides* (Rss.).
2. Fig. 23. Planorbulina angulata. According to Reuss=*Pl. ammonoides* (Rss.).
3. Not figured. —— umbilicata. According to Reuss=*Anomalina complanata* (Rss.), which is evidently *Planorbulina* (*Anomalina*) *rotula* (D'O.).
4. Not figured. Truncatulina sublævis. According to Reuss= *Tr. convexa*, Rss. (Thick *Tr. lobatula*.)
5. Fig. 22. Rotalia turgida. According to Reuss=*R. umbilicata*, D'O.
6. Not figured. Nonionina globosa. Figured by Reuss, *op. cit.* pl. 7. f. 2, as *Rotalia globosa*, and near *R. umbilicata*, D'O.
7. In Fr. von Hagenow's 'Die Bryozoen der Maastrichter Kreide-Bildung,' 1850, we see *Cymbalopora radiata*, von Hag., p. 104, pl. 12. fig. 18 (Carpenter's 'Introd. Foram.' p. 215).

3. A. E. REUSS. 'Versteinerungen der Böhmischen Kreideformation,' 1845–46 ; Rhizopoden, i. 1845, pp. 25–28, pls. 8, 12, & 13 ; ii. 1846, pp. 106–110, pls. 24 & 43.

1. Pl. 8. fig. 53, & pl. 13. fig. 66. Rosalina ammonoides. *Planorbulina* (subgenus *Anomalina*) *ammonoides*, very near to *Planorb.* (*Anom.*) *Lamarckiana* (D'O.), Foram. Canaries, pl. 2. figs. 13–15.
2. Pl. 12. fig. 17. Rotalina lenticula. *Planorbulina* near *P. Dutemplei* (D'O.).
3. 30, & pl. 13. fig 67. Rosalina moniliformis. *Pl.* (*Anom.*) near *Pl. ammonoides*.
4. 8. Rotalina nitida. *Pulvinulina* near *P. crassa* (D'O.).
5. 18. —— polyrraphes. *Planorb.* (*Truncatulina*), a neat and thick subvariety of *Tr. lobatula*.
6. Pl. 8. fig. 71. Truncatulina lævigata, *Rœm.* An attached *T. lobatula*?
7. Pl. 12. fig. 31. Rotalina Micheliniana, *D'O. Pulvinulina Micheliniana* (D'O.).
8. Pl. 8 fig. 52, & pl. 12. fig. 20. Rotalina nitida. *Pulvinulinæ* closely allied to *Pulv. Micheliniana* (D'O.) and *Pulv. crassa* (D'O.).

[Pl. 8. figs. 54, 74, & pl. 13. fig. 68, *Rosalina marginata*, is not a Rotaline, but a *Globigerina*, discoidal, neat, limbate, and hirsute; it is better figured, together with another specimen of the same kind, *Ros. canaliculata*, in Dr. Reuss's Memoir on the Chalk of the Eastern Alps, 1854, pl. 26. figs. 1 & 4. *Globig. Linnæi* (D'Orb.), 'Foram. Cuba,' pl. 5. f. 10–12 is similar, but without prickles. These are Globigerine *isomorphs* of *Planulina ariminensis*, *Discorbina biconcava*, and *Pulvinulina Menardii*. *Glob. marginata* (Rss.), is common in the English Chalk.]

4. Alois Alth. 'Geognostisch-paläontologische Beschreibung der nächsten Umgebung von Lemberg.' In *Haidinger's naturwiss. Abhandlungen*, vol. iii. 1850. Foraminifera, pp. 262–271.

1. Pl. 13. fig. 21. Rotalina depressa. *Planorb. ammonoides* (rather flat).
2. 20. Rosalina galiciana. *Truncat. lobatula.*

5. A. E. Reuss. 'Die Foraminiferen und Entomostraceen des Kreidemergels von Lemberg.' *Haidinger's naturw. Abhandl.* vol. iv. 1851. Foraminifera, pp. 22–46.

1. Pl. 4. fig. 2. Rotalina ammonoides. *Planorb. ammonoides.* See above.
2. 3. Anomalina complanata. *Pl.* (*Anom.*) *rotula* (D'O.).
3. 1. Rotalina polyrraphes. *Truncatulina.* See above.
4. Pl. 3. fig. 14. —— involuta. *Truncatulina* rather thicker than the *Tr. polyrraphes* (Rss.).
5. Pl. 4. fig. 4. Truncatulina convexa. Thicker still, only slightly differing from *Truncatulina Beaumontiana*, D'O.

6. A. E. Reuss. 'Beiträge zur Charakteristik der Kreideschichten in den Ostalpen, besonders im Gosauthal und am Wolfgangsee.' *Denksch. kais. Akad. Wissensch. Wien*, vol. vii. 1854. Foraminifera, pp. 66–72.

1. Pl. 25. fig. 15. Rotalina stelligera. *Pulvinulina* of the *elegans* group.
2. Pl. 26. fig. 2. Rosalina squamiformis. } *Pulvinulinæ*, extreme forms (peculiar
3. 3. —— concava. } to deep water) of the *Schreibersii* gr.
[4. —— canaliculata. } *Globigerina marginata* (Rss.). See above].
1. —— marginata. }

7. A. E. Reuss. 'Beitrag zur genaueren Kenntniss der Kreidegebilde Meklenburgs.' *Zeitschr. d. deutsch. geol. Gesell.* vol. vii. 1855, pp. 261–292.

1. Pl. 9. fig. 6. Rotalia Brueckneri. *Planorbulina Haidingerii* (D'O.).
2. 8. Rosalina Kochi. *Planorb.* (*Anom.*) *rotula* (D'O.).
3. Pl. 11. fig. 3. Rotalina deplanata. } *Truncat. lobatula*; neatly formed.
4. 4. Truncatulina concinna. }
5. Pl. 9. fig. 6. Rotalia Karsteni. *Pulvinulina*, one of the medium forms of the *Schreibersii* group, and near *Pulv. antillarum* (D'O.).

8. A. E. Reuss. 'Die Foraminiferen der Westphalischen Kreideformation.' *Sitzungsb. Akad. Wiss. Wien*, vol. xl. pp. 147 *et seq.* 1860.

1. Pl. 11. fig. 5. Rotalia umbonella, *Planorbulina* belonging to the *Ungeriana* subgroup.

2. Pl. 11. fig. 4. Rotalia exsculpta. A true *Rotalia*, near *R. ornata* (D'O.), Amér. Mérid. p. 40, pl. 1. figs. 18–20.
[6. Valvulina allomorphinoides, seems to be a *Sphæroidina* between *bulloides* and *dehiscens*.]

9. A. E. Reuss. 'Palæontologische Beiträge.' *Sitzungsb. math.-naturw. Cl. kais. Akad. Wiss. Wien*, vol. xliv. 1861.

I. 'Die Foraminiferen der Kreidetuffes von Maastricht,' pp. 304–324.

1. Pl. 2. fig. 2. Rotalia tuberculifera. *Planorbulina Ungeriana*, var. profusely granulated.
2. 4. —— involuta, var. *Pl. Ungeriana*, without even so many granulations as shown on D'Orbigny's figured specimen.
3. 5. —— hemisphærica. *Planorbulina* belonging to the *Haidingerii* group.
4. Pl. 3. fig. 2. Truncatulina tenuissima. *Planorb.* (*Anom.*) *rotula*, compressed subvariety.
5. 1. Rosalina Bosqueti. *Truncatulina lobatula.*
6. Pl. 2. fig. 3. —— Binkhorsti. *Discorbina Binkhorsti* (Rss.). Essentially the same as the somewhat slighter *D. valvulata* (D'O.), living at the Canary Islands and West Indies: this is a well-grown, limbate form, allied to *D. vesicularis* (D'O.), a subtype of *D. turbo* (D'O.), 'Phil. Trans.' vol. clv. p. 385.
7. Pl. 4. figs. 1–4, 6. Calcarina calcitrapoides (*Lamk.*), and f. 5, var. lævigata (*Lamk.*).
8. 7–9, and pl. 5. figs. 1–5. Orbitoides Faujasi (*Defr.*).

II. 'Die Foraminiferen der Schreibkreide von Rügen,' pp. 324–333.

1. Pl. 6. fig. 7, and pl. 7. fig. 1. Rotalia constricta, *v. Hag.* *Planorbulina ammonoides*, thin-edged.
2. Pl. 7. fig. 2. Rotalia globosa (*v. Hag.*). A true *Rotalia*, near *R. umbilicata*, D'O. See above, p. 106.

III. 'Die Foraminiferen des senonischen Grünsandes von New-Jersey,' pp. 334–340.

1. Pl. 8. fig. 1. Rotalia Mortoni. *Planorbulina Ungeriana*, thick subvariety.
2. Pl. 7. fig. 6. Truncatulina Dekayi. *Truncatulina lobatula*, neat form.

10. A. E. Reuss. 'Die Foraminiferen der norddeutschen Hils und Gault.' (Including also the Gault of Folkestone.) *Sitzungsb. Akad. Wiss. Wien*, vol. xlvi. 1863.

1. Pl. 10. fig. 3. Rotalia lenticula. *Planorbulina*, of the *Haidingerii* group.
2. Pl. 11. fig. 5. Rosalina Schlœnbachi. *Planorbulina*, a variety, with inflated chambers, between *Pl. Haidingerii* and *Ungeriana*.
3. 4. —— nitens. *Planorbulina*, a simple form of *Pl. farcta*.
4. Pl. 10. fig. 2. Rotalia nonionina. *Planorb.* (*Anom.*), a thick, few-chambered, subsymmetrical variety of *Pl. farcta*.
5. Pl. 11. fig. 6. Rosalina inflata. *Planorb.* close to *ammonoides*, but with large chambers, even larger relatively than in *Pl.* (*Anom.*) *badenensis*, D'O.
6. Pl. 13. fig. 1. Nonionina bathyomphalus. A very symmetrical (Anomaline) variety of *Planorbulina ammonoides* (Rss.).
7. Pl. 11. fig. 3. Rosalina complanata, *Rss.*, var. The same as *Pl.* (*Anom.*) *rotula*, D'O.

* Indicates the presence of the spec

1.

		Hils Clay and Gault, Germany.	Gault
More or less conical.	Planorbulina farcta (type)	†	[illegible]
	Haidingerii (*D'O.*)	†	†
	hemisphærica (*Rss.*)	......	....
	lenticula (*Rss.*)	*	....
	Schlœnbachi (*Rss.*)	*	
	Ungeriana (*D'O.*)	......	*
	tuberculifera[2] (*Rss.*)	......	...
	Mortoni (*Rss.*)	......	....
	umbonella (*Rss.*)	*	....
	fontana (*Karrer*)	......	....
	Clementiana (*D'O.*)	......	....

8. Pl. 11. fig. 7. Rosalina rudis. *Planorb.* (*Truncatulina*) *lobatula*, well grown, with full chambers.
9. 2. Rotalia sulcata. *Planorbulina.* The same as *Pl. sulcata* (Rœm.). See p. 106. *Truncatulina dispar*, D'O., and *Tr. advena*, D'O., are not distant allies, on the one hand; and *Pl. umbonella* (Rss.), on the other hand, leads it into *Pl. Ungeriana.*

10. Pl. 10. fig. 4. —— reticulata.
11. 5. —— Schlœnbachi.
12. 6. —— caracolla (*Rœm.*).
13. Pl. 13. figs. 3–5. —— spinulifera.
14. 6. —— Carpenteri.

(10–14:) All these are scarcely separable subvarieties, belonging to the "*elegans*" group of *Pulvinulina repanda* (F. & M.). The mutual alliance and gradational features of these and *Pulv. Orbignyi* and *Pulv. ornata* (Rœmer, see above, p. 106), can readily be seen on a comparison of the beautiful figures given by Reuss, and the less elaborate, but recognizable, figures in Rœmer's 'Norddeutsch. Kreidegeb.' Prof. Reuss finds *spinulifera* the most abundant form in the Gault of Folkestone. His *reticulata* is almost exactly the same as *P. Berthelotiana* (D'O.).

15. Pl. 10. fig. 7, & pl. 11. fig. 1. Rotalia hemisphærica (semiglobosa, in the text, p. 85). This is near *Pulv. Cordieriana* (D'O.), a smooth member of the "*elegans*" group of *Pulvinulina.*

11. F. Karrer. 'Ueber ein neues Vorkommen von oberer Kreideformation in Leitzersdorf bei Stockerau, und deren Foraminiferen.' *Jahrb. k. k. geol. Reichsanstalt*, 1870. Foraminifera, pp. 163–184.

1. Pl. 11. fig. 14. Truncatulina horrida. *Planorbulina Ungeriana*, granulose subvariety, rather thinner and poorer than *Pl. tuberculifera* (Rss.).
2. 15. Discorbina danubia. *Truncatulina lobatula.*
3. 16. Rotalia fontana. *Planorbulina* (*Anomalina*), a neat compact ornate form.

§ VII.—In selecting the figured varieties of *Planorbulinæ*, *Pulvinulinæ*, *Discorbinæ*, and *Rotaliæ* enumerated in the foregoing lists, as examples of the known Cretaceous Rotalinæ, we must not lose sight of the other Rotalines, such as *Calcarina*, *Cymbalopora*, *Patellina*, &c., in the Chalk and its associated strata. Of these, several interesting species are known. We must also explain that, besides the figured species and varieties, there are in most cases many allied forms enumerated in the respective memoirs, but not represented there, having been previously figured. Fortunately several of the forms noticed in the earlier memoirs have been refigured by our German fellow-labourers, in the first style of modern lithography, and with real naturalistic art. In the appended Table we have introduced, as far as we can recognize them, the other forms referred to, besides those figured in the several memoirs, for the different localities.

§ VIII.—As an example of a local group of Foraminifera of the Family Rotalinæ (Carpenter) amongst a special fauna, corresponding, though of later age, with such other groups as are depicted by

TABLE I.—*The range of the* ROTALINÆ *in the Cretaceous Formations.*

* Indicates the presence of the species or variety mentioned. † Indicates that the typical or subtypical species is represented by varietal forms.

		1. Hils Clay and Gault, Germany.	2. Gault, Kent &c.	3. Greensand, Warminster.	4. Greensand, New Jersey.	5. Chalk-marl, Kent.	6. Cretaceous (Pläner), Bohemia.	7. Cretaceous (Pläner), Lemberg, Styria.	8. Gosau &c., Eastern Alps.	9. Leitzerdorf, Austria.	10. Kanara-See, Dobrutscha[1].	11. Volsk, Russia.	12. Meudon &c., France.	13. Gravesend &c., England.	14. Westphalia. Lower.	15. Westphalia. Middle.	16. Westphalia. Upper.	17. Mecklenburg.	18. Möen.	19. Rügen.	20. Maestricht.	21. Missouri and Mississippi.	TERTIARY.	RECENT.
	PLANORBULINA FARCTA (type)	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	*	*
More or less conical.	Haidingerii (*D'O.*)	†	†	†	†	†	†	......	†	†	......	*	†	* Th	†	†	......	*	......	*	†	......	*	*
	hemisphærica (*Rss.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*			
	lenticula (*Rss.*)	*	......	......	......	......	*	......	......	......	......	......	......	......	*	*								
	Schlœnbachi (*Rss.*)	*																						
	Ungeriana (*D'O.*)	......	*	*	*	*	......	......	......	......	......	......	......	*	......	......	......	......	......	......	*	......	*	*
	tuberculifera[2] (*Rss.*)	......	......	......	......	......	......	......	......	*	......	......	......	......	......	......	......	......	......	......	*			
	Mortoni (*Rss.*)	......	......	......	*	......	......	......	......	......	......	......	......	......										
	umbonella (*Rss.*)	*	......	......	......	......	......	......	* G	......	......	......	......	......	*									
	fontana (*Karrer*)	......	......	......	......	......	......	......	......	*	......	......	......	......										
	Clementiana (*D'O.*)	......	......	......	......	......	......	......	......	......	......	......	*	*										
	Voltziana (*D'O.*)	......	......	......	......	......	......	......	......	......	......	......	*	*	......	......	......	......	......	......	*			
	? conica (*Rœm.*)	* Ro																						
	(*Anomalina*).																							
	nonionina (*Rss.*)	*																						
	inflata (*Rss.*)	*																						
	ammonoides (*Rss.*)	*	*	*	*	*	*	*	* G	†	†	†	*	*	......	*	*	†	*	*	*	*	*	*
	bathyomphala (*Rss.*)	*																						
More or less nautiloid.	moniliformis (*Rss.*)	......	......	......	......	......	*	......	......	......	......	......	......	......	......	......	*							
	Lorneiana (*D'O.*)	......	......	......	......	......	......	......	......	......	*	......	*	*										
	constricta (*von Hag.*)	......	......	......	......	......	......	......	* G	......	*	......	......	......	......	......	......	......	......	*				
	rotula[3] (*D'O.*)	......	......	......	......	......	......	*	*	......	......	......	......	......	......	*	......	*	......	*	......	......	*	
	tenuissima (*Rss.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*			
	nitens (*Rss.*)	*																						
	globulosa[4] (*Ehr.*)	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	......	......	*	*	......	*	*	*
	(*Planulina*).																							
	ariminensis (*D'O.*)	......	......	......	......	......	......	......	......	......	......	*	......	*	......	......	......	......	*	......	......	*	*	*
	(*Truncatulina*).																							
	variabilis (*D'O.*)	......	*																					
	lobatula (*W. & J.*)	* Ro	* D	*	*	......	*	*	†	*	†	......	†	*	†	†	†	†	......	†	*	......	*	*
	concinna (*Rss.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*						
Plano-convex (flat on one face).	sulcata (*Rœm. & Rss.*)	*	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	* ?
	Beaumontiana (*D'O.*)	......	......	......	*	......	......	......	......	......	......	......	*	*										
	convexa (*Rss.*)	......	......	......	......	......	......	*	* G	*	......	......	......	......	......	......	*	......	......	*				
	rudis (*Rss.*)	*																						
	polyrraphes (*Rss.*)	*	* R	......	*	......	*	*	* G	......	......	......	......	......	*	*	*							
	involuta (*Rss.*)	*	......	......	......	......	......	*	......	......	*	......	......	......	......	......	......	......	......	*	*			
	PULVINULINA REPANDA (type)	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	......	*	*
"Repanda" or "pulchella" group.	spatiosa (*Ehr.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	*	?
	squama (*Ehr.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*				
"Menardii" group.	Micheliniana (*D'O.*)	......	......	......	*	......	*	......	......	*	*	......	*	*	......	*	*	......	......	*	......	......	*	*
	truncatulinoides (*D'O.*)	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	......	......	......	......	......	......	?	*
	crassa (*D'O.*)	......	......	......	......	......	......	......	......	......	......	......	*	*	......	......	......	......	......	......	......	......	?	*
	nitida (*Rss.*)	*	......	......	*	......	*	*	......	......	......	......	......	......	......	*	*							
	Cordieriana[5] (*D'O.*)	......	......	......	......	......	......	......	......	......	......	......	*	*	......	......	......	......	......	......	*			
	Menardii (*D'O.*)	†	......	......	†	*	†	†	......	†	†	......	†	†	......	†	†	......	......	†	†	......	*	*
	hemisphærica (*Rss.*)	*																						
	stelligera (*Rss.*)	......	......	......	......	......	......	......	*															
	Carpenteri (*Rss.*)	......	* R																					
	Schlœnbachi (*Rss.*)	*																						
"Elegans" group.	elegans (*D'O.*)	†	†	†	......	......	......	......	†	......	......	†	......	......	......	......	......	......	* ?	......	......	......	*	*
	caracolla (*Rœm.*)	* Ro	*	*	......	......	......	......	......	......	......	*												
	reticulata (*Rss.*)	*																						
	spinulifera (*Rss.*)	......	* R																					
	Orbignyi (*Rœm.*)	* Ro	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	* ?					
	ornata (*Rœm.*)	* Ro																						
"Schreibersii" group.	Karsteni (*Rss.*)	......	......	......	*	......	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	......	*	*
	squamiformis (*Rss*)	......	......	......	......	......	......	......	*															
	concava (*Rss.*)	......	......	......	......	......	......	......	*															
	CYMBALOPORA POEYI (type)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*
	radiata (*von Hag.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*			
	ROTALIA BECCARII (type)	......	†	......	......	......	......	......	†	†	†	......	†	†	......	......	†	......	......	†	......	......	*	*
	exsculpta (*Rss.*)	......	......	......	......	......	......	......	* G	......	......	......	......	......	......	......	*							
	umbilicata (*D'O.*)	......	* B	......	......	......	......	......	* G	*	*	*	*	*	......	......	......	......	......	*	......	......	*	*
	globosa (*von Hag.*)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*				
	CALCARINA Spengleri	......	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	......	......	......	*	......	?	*
	TINOPORUS LÆVIS (type)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*
	concavus (*Lamarck*)	......	......	* ?	......	*	......	......	......	......	......	......	......	*	*									
	globularis (*Phillips*)	......	......	......	......	*	*	......	......	......	......	......	*	*	*									
	PATELLINA CONCAVA (type)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*
	lenticularis (*Blumenbach*)	......	*																					
	ORBITOIDES Faujasii	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	......	......	......	......	*			

In column 1, Ro shows the species indicated by F. A. Rœmer. In column 2, R shows the species indicated by Reuss; and B means occurrences at Biggleswade, Bedfordshire.

In column 8, G is attached to the species indicated by Gümbel as occurring in the Gosau-marls and Belemnitella-beds of the Bavarian Alps; *Sitzungsb. Bayr. Akad. Wiss.* 1870, pp. 283 & 287. In column 13, Th means Thorpe, near Norwich.

[1] The *Rotalinæ* of this column are taken from Prof. A. E. Reuss's paper on the Foraminifera and Ostracoda of the Chalk at Kanara Lake, near Kustendje, Bulgaria: *Sitzungsb. Akad. Wiss. Wien*, vol. lii. 1865.

[2] Including *Pl. horrida*, Kar.

[3] Including *Pl. complanata* (Rss.).

[4] Most probably Planorbuline; but in some cases possibly referable to other forms.

[5] Possibly a member of the "elegans" group.

Reuss from the Bohemian, the Westphalian, and other Cretaceous formations, we here enumerate the Rotalinæ which D'Orbigny figured and described in 1846 from the Miocene strata of the neighbourhood of Vienna. And we reduce his nomenclature to that adopted by ourselves, so that the comparison of varieties (or, rather, in most cases, subvarieties) may readily be made by others. Were, for instance, all the Cretaceous Planorbuline *Rotalinæ* figured by Reuss, and all these Tertiary Planorbulines figured by D'Orbigny, copied out on a sheet of paper, and arranged in the order of their alliances, a close *specific* relationship would be clearly observed, but modified by varietal and subvarietal (or rather individual) differences, which give the groups a different *facies*. So also the several Cretaceous faunas, local or successive, will be found to have somewhat different *facies*, without changing much as to species and definite varieties.

For another reason, too, have we produced this critical list of the fossil Rotalinæ from Vienna,—because the naming of these and of some of the German Cretaceous Foraminifera by Prof. Reuss was contemporaneous. It is, however, the naming of the *type* (or average form) of a group or subgroup that takes priority among Foraminifera, the names of minor varieties becoming merged in those of the more important types, as we have stated elsewhere.

The 'Foram. Foss. Bassin de Vienne,' is also an accessible book for most students; and other species determined by D'Orbigny in former years can be readily found in the 'Ann. Nat. Hist.' of 1865 and 1871, in plates attached to memoirs by ourselves and our colleague Mr. H. B. Brady.

1. For the *Planorbulinæ*, which chiefly concern us now, it will be remembered that *Pl. farcta* (Fichtel & Moll) is the type; *Pl. tuberosa* (F. & M.) is the subtype; and all other known forms of *Planorbulina* can be grouped with one or the other of these. Or, in other words, *Pl. farcta* may be termed the species, *Pl. tuberosa* the chief variety, and other forms inferior varieties of one or the other. This is zoologically true, though rather confusing. At all events, in indicating the *precise* relationships of the *Planorbulinæ*, the latter plan has to be followed. A critical account of *Planorbulinæ*, *Pulvinulinæ*, *Discorbinæ*, and *Rotaliæ*, useful to the readers of this paper, will be found in the 'Phil. Trans.' 1865, pp. 378 *et seq.*

Rotalinæ *extracted from A. d'Orbigny's 'Foraminifères fossiles du Bassin tertiaire de Vienne,'* 1846.

Plate VII.

Figs. 19–21. Rotalina kalembergensis. *Planorbulina*, a compressed variety of *Pl. tuberosa* (F. & M.), near *Pl. Dutemplei* (D'O.), but thinner.
22–24. —— Hauerii. *Pulvinulina* near *P. auricula* (F. & M.).
25–27. —— Boueana. *Pulvinulina* near *P. pulchella* (D'O.).
28–30. —— Partschiana. *Pulvinulina* near *P. peruviana* (D'O.).

Plate VIII.

Figs. 1–3. —— Partschiana. *Pulvinulina* near *P. peruviana* (D'O.).
4–6. —— Schreibersii. *Pulvinulina* near *P. Alvarezii* (D'O.).
7–9. —— Haidingerii. *Planorbulina*, a conical subvariety of *Pl. tuberosa* (F. & M.).

Figs. 10–12. Rotalina Soldanii. *Rotalia* near *R. umbilicata* (D'O.).
13–15. —— Akneriana. *Planorbulina*(*Truncatulina*), stout, compact, and many-chambered variety of *Pl. farcta*; or it may be regarded as a variety of *Pl. tuberosa,* quite flattened on one face.
16–18. —— Ungeriana. *Planorbulina* (*Anomalina*), neat, compressed, and symmetrical subvariety of *Pl. tuberosa.*
19–21. —— Dutemplei. *Planorbulina,* a subvariety of *Pl. tuberosa,* much depressed on one face.
22–24. —— Brongniartii. *Pulvinulina auricula* (F. & M.).
25–27. —— aculeata. *Calcarina Spengleri* (Gm.), var.

PLATE IX.

Figs. 16–17. Planorbulina mediterranensis. *Planorbulina,* var. of *Pl. farcta* (F. & M.).
18–23. Truncatulina lobatula (W. & J.). *Pl.* (*Truncat.*), a variety or arrested form of *Pl. farcta.*
24–26. —— Boueana. *Pl.* (*Tr.*) *lobatula* (W. & J.), a neat and round subvariety.
27–29. Anomalina variolata. *Pl.* (*Tr.*) *lobatula,* coarse-pored.

PLATE X.

Figs. 1–3. Anomalina badenensis. *Planorbulina* (*Anomalina*), a discoidal, inflated subvariety of *Pl. tuberosa.*
4–9. —— austriaca. *Planorb.* (*Anom.*), discoidal, compressed, a thin-edged subvariety of *Pl. tuberosa,* =*ammonoides* (Rss).
10–12. —— rotula. *Pl.* (*Anom.*), a flat subvariety of *Pl. tuberosa.*
13–15. Rotalina complanata. *Discorbina,* a neat, compact, helicoid subvariety of *D. elegans* (D'O.).
16–18. —— imperatoria. *Discorbina* related to *D. pileolus* (D'O.).
19–21. —— dubia. ?
22–24. —— viennensis. *Rotalia,* var. of *R. Beccarii* (Lin.).
25–27. —— simplex. *Planorbulina,* a simple, neat, helicoid subvariety of *Pl. tuberosa.*

PLATE XI.

Figs. 1–3. Asterigerina planorbis. *Discorbina rosacea* (D'O.), a thick specimen.
4–6. Rosalina obtusa. *Discorbina,* a good variety, related to *D. globularis* (D'O.).

2.—To apply this critical determination of D'Orbigny's Viennese species to our study of the Cretaceous ROTALINÆ, we must group them in their natural order, so as to render them comparable with the Table of Cretaceous Rotalines appended to this memoir; we must also insert with them such other forms from the Vienna Tertiary beds as Cžjžek, Reuss, and Karrer have discovered.

Those figured and described by Karrer are as follows:—

Anomalina Suessi, *Karrer**. Sitzb. Ak. W. 1861, xliv. pl. 2. f. 2. A very much compressed *Anomalina austriaca,* D'O. From Ödenburg.

Rotalia speciosa, *Karrer.* Sitzb. Ak. W. 1864, pl. 2. f. 12. *Anomalina coronata,* P. & J. From Baden.

Rotalia scutellaris, *Karrer.* Sitzb. Ak. W. 1864, l. pl. 2. f. 13. *Planorbulina Haidingerii* (D'O.), subvariety. From Mödling.

Rosalina granulosa, *Karrer.* Sitzb. Ak. W. 1864. l. pl. 2. f. 14. *Cymbalopora granulosa* (Karrer). From Forchtenau.

Rotalia tuberosa, *Karrer.* Sitzb. Ak. W. 1867, lv. pl. 1. f. 4. *Rotalia Schrœteriana,* P. & J. From Laa, Lower Austria.

Globigerina arenaria, *Karrer.* Sitzb. Ak. W. 1867, lv. pl. 1. f. 10. (Non *Globigerina.*) *Discorbina?* From Grund, Lower Austria.

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* Some valuable Tables of the distribution of the Foraminifera in the several formations of the Vienna Basin are given by Herr Felix Karrer in his paper "Ueber das Auftreten," &c. in the Sitzungsberichte, 1861–67.

The species determined by Czjžek and Reuss are indicated, with references, in the following list, which gives the results of our critical study of the published forms of Miocene Foraminifera from Lower Austria (Vienna Basin).

Foraminifera from Tertiary strata of the Vienna Basin, after D'Orbigny, Czjžek, Reuss, and Karrer.

Planorbulina farcta (type).

Conical varieties.	Planorbulina Haidingerii (*D'O.*).
	P. scutellaris (*Karrer*).
	P. reticulata (*Cz.* * pl. 13. f. 7–9).
	P. (Siphonia) fimbriata (*Rss.*† pl. 47. f. 6) = *Pl. reticulata* (Cz.).
	P. kalembergensis (*D'O.*).
	P. Ungeriana (*D'O.*).
	P. Dutemplei (*D'O.*).
	P. affinis (*Cz.* pl. 12. f. 36–38) = *Pl. Dutemplei* (D'O.).
	P. Akneriana (*D'O.*).
	P. cryptomphala (*Rss.* pl. 47. f. 2.) = *Pl. Akneriana* (D'O.).
Nautiloid varieties.	P. badenensis (*D'O.*).
	P. austriaca (*D'O.*).
	P. rotula (*D'O.*).
	P. simplex (*D'O.*).
	P. Suessi (*Karrer*).
	P. speciosa (*Karrer*) = *Pl. coronata*, P. & J.
Plano-convex varieties.	P. mediterranensis, *D'O.*
	Truncatulina lobatula (*W. & J.*).
	T. Boueana, *D'O.*
	T. variolata (*D'O.*).

Pulvinulina repanda (type).

"Elegans" group.	Pulvinulina Partschiana (*D'O.*).
	P. badenensis (*Cz.* pl. 13. f. 1–3).
"Schreibersii" group.	P. Schreibersii (*D'O.*).
	P. spinimargo (*Rss.* pl. 47. f. 1).
"Auricula" group.	P. Boueana (*D'O.*).
	P. Brongniartii (*D'O.*).
	P. scaphoidea (*Rss.* pl. 47. f. 3).
	P. Hauerii (*D'O.*).

Discorbina turbo (type).

Discorbina complanata (*D'O.*).
D. imperatoria (*D'O.*).
D. planorbis (*D'O.*) = *D. rosacea* (D'O.).
D. obtusa (*D'O.*).
D. patella (*Rss.* pl. 46. f. 22).
D. nana (*Rss.* pl. 46. f. 23.).
D. arenata (*Rss.* pl. 47. f. 4).
? D. arenaria (*Karrer*).
? D. dubia (*D'O.*).

Rotalia Beccarii (type).

Rotalia tuberosa, *Karrer*, = *R. Schrœteriana*, P. & J.
R. viennensis (*D'O.*).
R. Soldanii, *D'O.*
R. conoidea (*Cz.* pl. 13. f. 4–6) = *R. Soldanii*, D'O.

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* Johann Czjžek, "Beitrag zur Kenntniss der fossilen Foraminiferen des Wiener Beckens." *Haidinger's naturwiss. Abhandl.* vol. ii. 1848.

† A. E. Reuss, "Neue Foraminiferen aus der Schichten des österreichischen Tertiärbeckens." *Denkschr. Akad. Wiss. Wien*, vol. i. 1850, pp. 365–390.

CALCARINA SPENGLERI (type).
Calcarina aculeata (*D'O.*).

CYMBALOPORA POEYI (type).
Cymbalopora granulosa (*Karrer*).

The relationship between the fossil fauna of Vienna and the living Foraminifera of the Mediterranean is shown in the Table opposite to page 302, Quart. Journ. Geol. Soc. vol. xvi. The species there numbered 104–107 are *Planorbulinæ*; 108–118 are *Pulvinulinæ*; 119–123 are *Rotaliæ*; and 127–132 are *Discorbinæ*.

§ IX.—To render our conception of the Rotaline portion of local and successive Foraminiferal faunæ more complete, we here add tabular abstracts of those treated of by D'Orbigny from the West Indies*, the Canary Islands†, and South America‡, revising his nomenclature. The ROTALINÆ which we have described from the Arctic and North-Atlantic Oceans are also herewith tabulated. Thus we shall have before us comparative synopses of this important and characteristic Rhizopodal group, not only from several parts of the great Atlantic, but from the long-preceding Cretaceous ocean. This old water-area was not so wholly altered by changed limits and oscillating floor, but that its deeper portions may have continued as the sunken abysses of succeeding periods, and not ceased to receive the shells and ooze of succeeding generations.

An intermediate and local fauna, also, is represented in the Table of the fossil Rotalines from the vicinity of Vienna, such as lived in a large but "mediterranean" sea succeeding (not immediately) a portion of the Cretaceous ocean, after the Nummulitic ocean had been formed by limitation of the latter, and had itself dwindled into the Mid-Tertiary seas, one of which the Viennese deposits under notice represent.

The "Nummulitic" period had Rotalines of very great interest, which we treat of in three selected lists further on. To complete the subject, we will in another paper give a sketch of the distribution of the very important genus *Globigerina*, including its earlier and present stages of existence.

1. *Rotaline Foraminifera from Cuba, West Indies.* D'Orbigny, 1839.

PLANORBULINA FARCTA (type).

Conical.	Pl. 3. f. 9–11.	Planorbulina rosea, *D'O.* (A. d'Orbigny's Modèles, No. 35).
Plano-convex.	Pl. 6. f. 11–15.	Pl. vulgaris, *D'O.* = *Pl. mediterranensis*, D'O.
	Pl. 3. f. 6–8.	Truncatulina Candei, *D'O.* Close to *T. lobatula*.
	Pl. 6. f. 8–10.	T. Edwardsiana (*D'O.*). Limbate on one face.
	f. 3–5.	T. advena, *D'O.* *Tr. lobatula*, neat and many-chambered.

* Hist. Nat. Cuba, Foraminifères, 1839.

† Hist. Nat. Canaries, Foraminifères, 1839.

‡ Voyage Amér. Mérid., Foraminifères, 1839. See Ann. N. Hist. ser. 4, vol. viii. p. 253, &c.

PULVINULA REPANDA (type).

"Repanda" group.	Pl. 5. f. 4–6. Pulvinulina antillarum (*D'O.*). Near *P. punctulata* (D'O.) f. 1–3. P. caribæa (*D'O.*). Near *P. pulchella* (D'O.).
"Menardii" group.	f. 7–9. P. cultrata (*D'O.*). Pl. 2. f. 29, 30, & Pl. 3. f. 1. P. dubia (*D'O.*).
"Auricula" group.	Pl. 5. f. 13–15. P. Sagra (*D'O.*)=*P. auricula* (F. & M.). Pl. 4. f. 9–11. P. deformis (*D'O.*).

DISCORBINA TURBO (type).

Pl. 3. f. 21–23. Discorbina valvulata (*D'O.*). A limbate variety of *D. globularis*, Modèles, No. 69.
Pl. 4. f. 2–4. D. Candeiana (*D'O.*) = *D. globularis* (D'O.)
f. 5–8. D. Auberii (*D'O.*).
Pl. 3. f. 15–17. D. semistriata (*D'O.*).
f. 24, 25, & Pl. 4. f. 1. D. opercularis (*D'O.*).

ROTALIA BECCARII (type).

Pl. 4. f. 22–24. Rotalia Catesbyana (*D'O.*). f. 25–27. R. Parkinsoni (*D'O.*).	Varieties scarcely separable from *R. Beccarii*.
Pl. 5. f. 16–18. R. pulchella (*D'O.*).	Spinous variety.
f. 19–21. R. lobata (*D'O*). f. 25, & Pl. 6. f. 1. 2. R. carinata (*D'O.*).	Astral or asterigerine varieties.

CALCARINA SPENGLERI (type).

Pl. 5. f. 22–24. Calcarina calcar (*D'O.*).

CYMBALOPORA POEYI (type).

Pl. 3. f. 18–20. Cymbalopora Poeyi (*D'O.*).
f. 12–14. C. squamosa (*D'O.*).
f. 2–5. C. bulloides (*D'O.*).

2. *Rotaline Foraminifera from the Canaries.* D'Orbigny, 1839.

PLANORBULINA FARCTA (type).

Plano-convex varieties.	Pl. 2. f. 30. Planorbulina vulgaris, *D'O.*=*Pl. mediterranensis*, *D'O.* f. 22–24. Truncatulina lobata, *D'O.* = *Tr. lobatula* (W. & J. f. 29. T. variabilis, *D'O.* Wild-growing *Tr. lobatula.*

PULVINULINA REPANDA (type).

"Menardii" group.	Pl. 2. f. 25–27. Pulvinulina truncatulinoides (*D'O.*). f. 34–36. P. canariensis (*D'O.*) f. 37–39. P. Berthelotiana (*D'O.*).
"Elegans" group.	f. 31–33. P. hirsuta (*D'O.*).
"Auricula" group.	f. 40–42. P. oblonga (*D'O.*). f. 43–45. P. excavata (*D'O.*).

DISCORBINA TURBO (type).

Pl. 2. f. 19–21. Discorbina valvulata (*D'O.*). Pl. 1. f. 28–30. D. Berthelotiana (*D'O.*).	In the form of *D. Binkhorsti*, this is the oldest known *Discorbina*.

ROTALIA BECCARII (type).

Pl. 2. f. 16–18. Rotalia contecta, *D'O.* Near *R. Soldanii.*
f. 13–15. R. Lamarckiana, *D'O.* Near *R. orbicularis.*

3. *Rotaline Foraminifera from South America.* D'Orbigny, 1839.

I. From the Atlantic.

PLANORBULINA FARCTA (type).

Nautiloid. Pl. 6. f. 1–3. Planorbulina vermiculata (*D'O.*).
Plano-convex. Pl. 5. f. 25–27. Truncatulina dispar, *D'O.* *Tr. lobatula.*

PULVINULA REPANDA (type).

"Schreibersii" group. { Pl. 2. f. 6–8. Pulvinulina patagonica (*D'O.*).
Pl. 1. f. 21, & Pl 2. f. 1, 2. P. Alvarezii (*D'O*).

DISCORBINA TURBO (type).

Pl. 2. f. 12–14. Discorbina rugosa (*D'O.*).
Pl. 6. f. 10–12. D. Isabelleana (*D'O.*).
f. 13–15. D. Villardeboana (*D'O.*).

ROTALIA BECCARII (type)

Pl. 1. f. 18–20. Rotalia ornata (*D'O.*). { Subglobular, limbate variety of *R. Beccarii.*
Pl. 2. f. 18–20. R. monticula (*D'O.*). { Asterigerine variety of *R. Beccarii.*

II. From the Pacific*.

PLANORBULINA FARCTA (type).

Plano-convex. { Pl. 6. f. 4–6. Truncatulina depressa, *D'O.* A thin *Tr. lobatula.*
f. 7–9. Tr. ornata, *D'O.* Slightly limbate.

PULVINULINA REPANDA (type).

"Schreibersii" group. } Pl. 2. f. 3–5. Pulvinulina peruviana (*D'O.*).
"Auricula" group. { f. 15–17. P. auris (*D'O.*).
Pl. 7. f. 10–12. P. inæqualis (*D'O.*).

DISCORBINA TURBO (type).

Pl. 1. f. 15–17. Discorbina pileolus (*D'O.*).
Pl. 6. f. 16–18. D. araucana (*D'O.*).
Pl. 7. f. 7–9. D. inflata (*D'O.*). Thick *D. elegans.*
Pl. 1. f. 12–14. D. peruviana (*D'O.*). Near to *D. globularis.*
Pl. 2. f. 9–11. D. Saulcyi (*D'O.*).
Pl. 6. f. 19–21. D. Cora (*D'O.*).

ROTALIA BECCARII (type).

Pl. 7. f. 1–3. Rotalia inca (*D'O.*). A thin *R. Beccarii.*
f. 4–6. R. consobrina (*D'O.*). A helicoid *R. Beccarii.*

We are well assured that the foregoing lists represent portions only, and those chiefly littoral, of the several Foraminiferal faunas;

* Other local faunas from the Pacific may be collected from the Tables vii. and x. in the 'Phil. Trans.' 1865.

but we have no hesitation in offering them to the student as representative examples, and as nuclei for further observations.

4. *Rotaline Foraminifera from the Arctic Ocean.* Parker & Jones, 1865. *Phil. Trans.* vol. clv. pp. 338 &c.

PLANORBULINA FARCTA (type).

Nautiloid. Planorbulina (Anomalina) coronata, *P. & J.*
Plano-convex. Pl. (Truncatulina) lobatula (*W. & J.*)

PULVINULINA REPANDA (type).

"Repanda" group. Pulvinulina punctulata (*D'O.*).
"Menardii" group. Pulv. Micheliniana (*D'O.*).
"Schreibersii" group. Pulv. Karsteni (*Rss.*).

SPIRILLINA VIVIPARA (type).

DISCORBINA TURBO (type).

Discorbina globularis (*D'O.*). D. obtusa (*D'O.*).

PATELLINA CONCAVA (type).

Patellina corrugata, *Williamson.*

5. *Rotaline Foraminifera from the North-Atlantic Ocean.* Parker & Jones, 1865. *Phil. Trans.* vol. clv. pp. 338, 432, &c.

PLANORBULINA FARCTA (type).

Conical. { Planorbulina Haidingerii (*D'O.*). Pl. Ungeriana (*D'O.*).
Nautiloid. Pl. (Anomalina) coronata, *P. & J.*
Plano-convex. { Pl. mediterranensis, *D'O.* Pl. (Truncatulina) lobatula (*W. & J.*). Pl. (Tr.) refulgens (*Montf.*).

PULVINULINA REPANDA (type).

"Repanda" group. { Pulvinulina repanda (*F. & M.*) P. concentrica, *P. & J.*
"Menardii" group. { P. Menardii (*D'O.*). P. pauperata, *P. & J.* P. canariensis (*D'O*). P. Micheliniana (*D'O.*).
"Elegans" group. P. elegans (*D'O.*).
"Schreibersii" group. P. Karsteni (*Rss.*).

DISCORBINA TURBO (type).

Discorbina rosacea (*D'O.*). D. globularis (*D'O.*).
D. ochracea (*Will.*). D. Berthelotiana (*D'O.*).

ROTALIA BECCARII (type).

Rotalia Beccarii (*Lin.*). R. Soldanii (*D'O.*).
R. nitida, *Will.* R. orbicularis (*D'O.*).

TINOPORUS LÆVIS (type).

Tinoporus lævis, *P. & J.*

PATELLINA CONCAVA (type).

Patellina corrugata, *Will.*

6. *Rotalinæ from the Tropical Atlantic.* Parker & Jones, *Phil. Trans.* vol. clv. 1865, Tables vii. & x., column 21.

PLANORBULINA FARCTA (type).

Conical.	Planorbulina Clementiana (*D'O.*).	
	Pl. culter, *P. & J.*	
Plano-convex.	Truncatulina lobatula (*W. & J.*).	

PULVINULINA REPANDA (type).

"Menardii" group.	Pulvinulina cuneiformis, *P. & J. MS.*	P. Micheliniana (*D'O.*).
	P. Menardii (*D'O.*).	P. canariensis (*D'O.*).
	P. crassa, (*D'O.*).	P. pauperata, *P. & J.*
"Elegans" group.	P. elegans (*D'O.*).	

7. *Rotalinæ from the Abrolhos Bank, South Atlantic.* Parker & Jones, Phil. Trans. clv. 1865, Tables vii. & x., Columns 22, 23, 24.

PLANORBULINA FARCTA (type).

Conical	Planorbulina Haidingerii (*D'O.*).
	—— Ungeriana (*D'O.*).
	—— (Siphonina) reticulata (*Cz.*).
Nautiloid	—— ammonoides (*Rss.*).
	—— ariminensis, *D'O.*
Plano-convex	—— mediterranensis, *D'O.*

PULVINULINA REPANDA (type).

"Repanda" Group ...	Pulvinulina pulchella (*D'O.*).
"Menardii" Group ...	—— Menardii (*D'O.*).
	—— canariensis (*D'O.*).
	—— Micheliniana (*D'O.*).
	—— crassa (*D'O.*).
"Schreibersii" Group.	—— Schreibersii (*D'O.*).
	—— Karsteni (*Rss.*).
"Elegans" Group.......	—— elegans (*D'O.*).

DISCORBINA TURBO (type).

Discorbina globularis (*D'O.*).
—— rosacea (*D'O.*).
—— Berthelotiana (*D'O.*).

CYMBALOPORA POEYI (*D'O.*).

§ X.—Having thus provided a series of synoptical views of the Rotaline faunas in the several Cretaceous periods, in a Mid-Tertiary period, and in the existing Atlantic Ocean, as far as present opportunities permit, we will make the series more complete by supplying a link between the Chalk and the Miocene—namely, the Rotalines of the London Clay, of the Kressenberg Nummulitic, and the Paris Tertiaries,—and one between the Mid-Tertiary and the existing times, namely the Rotalines of the Crag of Suffolk and Antwerp.

1. *Rotalines from the Lower Eocene (Nummulitic) Strata of Kressenberg, North Alps.* C. W. Gümbel, 1868. *Abhandl. k. bayr. Akad. Wiss. Cl.* 2, vol. x.

PLANORBULINA FARCTA (type).

Conical	Planorbulina megomphalus (*Gümb.*).	Near *Pl. Haidingerii* (D'O.)
	Pl. pteromphalia (*Gümb.*).	
	Pl. kallomphalia (*Gümb.*).	
	Pl. truncana (*Gümb.*).	Near *Pl. Ungeriana* (D'O.).
	? Pl. eocana (*Gümb.*). ?	
	? Pl. subumbonata (*Gümb.*). ?	
Nautiloid	Pl. capitata (*Gümb.*)	Near *Pl.* (*Anomalina*) *ammonoides* (Rss.).
	Pl. rudis (*Gümb.*	
	Pl. grosserugosa (*Gümb.*).	
	Pl. cochleata (*Gümb.*).	Near *Pl.* (*Anom.*) *coronata*, P. & J.
	Pl. calymene (*Gumb.*).	
	Pl. cristata (*Gümb.*).	=*Pl. coronata*, P. & J.
Plano-convex	Truncatulina ammophila, *Gümb.*	Near *Pl.* (*Trun.*) *lobatula* (W. & J.).
	Tr. macrocephala, *Gümb.*	
	Tr. sublobatula, *Gümb.*	

PULVINULINA REPANDA (type).

"Menardii" Group	Pulvinulina bimamata (*Gümb.*).	
	P. campanella (*Gümb.*).	
	P. asterites (*Gümb.*).	A deep-sea form of *P. Menardii.*

DISCORBINA TURBO (type).

Discorbina polysphærica (*Gümb.*).
D. megasphærica (*Gümb.*) = *D. globigerinoides*, P. & J. *Phil. Trans.* clv. p. 421.

2. *Rottaline Foraminifera from the London Clay (Eocene).* Jones & Parker. 'Geologist,' vol. vii. p. 83, &c. 1854.

PLANORBULINA FARCTA (type).

Conical	Planorbulina Haidingerii (*D'O.*).
	Pl. Ungeriana (*D'O.*).
Nautiloid	Pl. ammonoides (*Rss.*).
Plano-convex	Truncatulina lobatula (*W. & J.*).

PULVINULINA REPANDA (type).

"Menardii" Group	Pulvinulina Micheliniana (*D'O.*).
"Elegans" Group	P. elegans (*D'O.*)

ROTALIA BECCARII (type).

Rotalia orbicularis (*D'O.*).

In the Paris Tertiaries (Grignon, &c.), the *Discorbinæ* are very numerous, varied, and characteristic, as seen in the annexed list; and in comparing the European Eocene *Foraminifera* with existing forms, we must remember that it is to the Red Sea, and particularly to the Australian seas, rather than the Atlantic, that we have to look for their recent analogues.

3. *Rotaline Foraminifera from the Eocene Tertiaries of Grignon, &c., France.* Compiled from Authors and Collections.

PLANORBULINA FARCTA (type).

Nautiloid..................	Planorbulina (Anomalina) coronata, *P. & J.* (From the Eocene of Normandy.)
Plano-convex..............	Pl. mediterranensis, *D'O.* Pl. (Truncatulina) lobatula (*W. & J.*). Pl. (Tr.) depressa (*Lamk.*).

PULVINULINA REPANDA (type).

"Auricula" Group ...	Pulvinulina auricula (*D'O.*). P. excavata (*D'O.*).

SPIRILLINA VIVIPARA, Ehr.

DISCORBINA TURBO (type).

Discorbina trochidiformis (*Lam.*).
—— turbo (*D'O.*).
—— lenticulina (*Lam.*).
—— rosacea, (*D'O.*).
—— pileolus (*D'O.*).
—— vesicularis (*Lam.*).
—— Gervillii (*D'O.*).
Discorbina rimosa, *P. & J.*
—— elegans (*D'O.*).
—— globularis (*D'O.*).
—— globigerinoides, *P. & J.*
—— parisiensis, *D'O.*
—— Berthelotiana, *D'O.*

ROTALIA BECCARII (type).

Rotalia Beccarii (*Linn.*).
—— ariminensis (*Lam.*).
Rotalia carinata (*D'O.*).

CALCARINA SPENGLERI (type).

Calcarina armata (*D'O.*).

PATELLINA CONCAVA (type).

Patellina corrugata, *Williamson.*
—— semiannularis, *P. & J.*
Patellina simplex, *P. & J.*

TINOPORUS LÆVIS, P. & J.

POLYTREMA MINIACEUM (Esper).

4. *Rotaline Foraminifera from the Crag of Eastern England (Pliocene).* Jones, Parker, and Brady, *Monogr. Foram. Crag* (Pal. Soc.), 1866.

PLANORBULINA FARCTA (type).

Conical	Planorbulina Haidingerii (*D'O.*). Pl. Ungeriana (*D'O.*).
Plano-convex	Pl. mediterranensis (*D'O.*). Truncatulina lobatula (*W. & J.*). Tr. refulgens (*Montf.*).

PULVINULA REPANDA (type).

"Repanda" group	Pulvinulina repanda (*F. & M.*). P. pulchella (*D'O.*).
"Auricula" group	P. auricula (*F. & M.*).
"Schreibersii" group...	P. Karsteni (*Rss.*).
"Elegans" group	P. elegans (*D'O*).

SPIRILLINA VIVIPARA, Ehr.

ROTALIA BECCARII (type).

Rotalia Beccarii (*Lin.*). R. orbicularis (*D'O.*).

TINOPORUS LÆVIS, P. & J.

5. *Rotalinæ from the Antwerp Crag.* Reuss*, *Sitzungsb. Akad. Wiss. Wien.* vol. xlii. pp. 355 *et seq.* 1860.

PLANORBULINA FARCTA (type).

Conical ...... { Planorbulina kalembergensis (*D' O.*).
Pl. tenuimargo (*Rss.* pl. 1. f. 11).

Plano-convex. Truncatulina varians, *Rss.* (Pl. 2. fig. 12). Thick *Tr. lobatula*, or, rather, *Pl. Ungeriana*, subvar.

PULVINULINA REPANDA (type).

"Auricula" group. Pulvinulina Brongniartii (*D' O.*).

ROTALIA BECCARII (type).

Rotalia Parkinsoniana (*D' O.*). R. orbicularis, *D' O.*

These types and subtypes are comprised also in the foregoing list of the Rotalines from the English Crag.

§ XI. *Conclusion.*—With reference to the Cretaceous Foraminifera, generally speaking, and as far as our observations lead us, we may say that, excepting *Discorbina Binkhorsti* (Rss.), of the Maestricht Chalk, there is no *Discorbina* known in this great series of formations; indeed that species seems to be the oldest of its genus. Of the other ROTALINÆ, there are numerous *deep-sea* forms of *Rotalia*, *Pulvinulina*, and *Planorbulina*. A rare *Calcarina* in our White Chalk, many in that of Maestricht, numerous *Orbitolinæ* (*Tinoporus* and *Patellina*) in some of the Cretaceous formations, and crowds of *Orbitoides* in some Chalk-strata of France and elsewhere, complete the Cretaceous Rotaline group.

With the closely allied *Globigerinæ*, on the one hand, and the *Nodosarinæ* (including *Cristellaria* &c.) on the other, the Rhizopodist has to deal largely when examining the Cretaceous rocks. In the former case, individuals, innumerable and variable, predominate, increasing in number upwards with the successive formations from the Neocomian to the Gault, Chalk-marl, and Chalk, in England. In the latter case the variations of all degrees and value become almost as numerous as the individuals; and these abound far more plentifully than the Rotalines. Such of the latter as we have more especially had to treat of in this memoir (namely, *Planorbulina*, *Pulvinulina*, and *Rotalia*) are more equally distributed all through this series of deposits.

Taking them in succession, we find that the typical *Planorbulina* is represented in all the columns of our Table. The subtype *Pl. Haidingerii*, taken as the leading form of the helicoid or conical Cretaceous forms, is represented in all the columns except 7, 10, 16, 18, and 21. The Nautiloid varieties, typified by *Pl. ammonoides*, occur in all except No. 14. The plano-convex or Truncatuline varieties, grouping around *Truncatulina lobatula*, fail only in Nos. 5, 11, 18, and 21. In all these cases the absence is probably not real; further search may supply such forms.

The *Pulvinulina* type of ROTALINÆ is also well represented in these Cretaceous deposits, as shown by our columns. Only No. 21

* See also Bullet. Acad. Roy. Sc. Belg. vol. xv. p. 154; and further on, p. 127.

fails to present some variety or subvariety of *Pulv. repanda.* Of the *Pulv.-Menardii* group there are representatives in Nos. 1, 4, 5, 6, 7, 9, 10, 12, 13, 15, 16, 19, and 20. Of the *elegans* group there are abundant and strongly marked forms in relatively few strata; and all but one of them are very close to, indeed scarcely separable from, the typical *elegans,* except by the comparative richness of the shell-growth. Columns 1, 2, 3, 8, 11, and 18 (?) have *Pulv. elegans* or some of its subvarieties; and its greatest abundance is decidedly with the Lower Cretaceous rocks. A very few *Pulvinulinæ* of the *Schreibersii* group are scattered here and there through the series—columns 4, 8, and 17.

Rotalia is represented by one variety of *R. Beccarii,* namely *R. exsculpta,* in columns 8 and 16, and far more persistently by the deep-sea variety *R. umbilicata* in Nos. 2, 8, 9, 10, 11, 12, 13, and 19.

All these typical species, and several of their varietal forms, have continued through the Tertiary period on to our own times, and are to be found in some existing sea or ocean. The chief distinction between the Cretaceous Rotalines and those of the present day is, that a vast number of varietal forms, which have sprung up during the intervening ages, indicate, by their multiplicity, the varying conditions of successive and changing marine areas, with differing limits, depths, and climates.

This is shown in Table II. (p. 123), by which we follow, though with unequal steps, the progressive development of the several types, as far as the materials before us will serve.

Thus the "conical" *Planorbulinæ* began early; they are present in the Lower Cretaceous deposits; they abound in the White Chalk, the Tertiary beds, and the Atlantic. *Pl. Ungeriana* is the most persistent form. The "nautiloid" or Anomaline *Planorbulinæ* abound in both the Lower and the Upper Cretaceous formations, and in the Tertiaries; but they are not so predominating in the Atlantic. *Pl. ammonoides* is the leading and lasting form. On the other hand, the "plano-convex" or Truncatuline *Planorbulinæ* have flourished freely throughout and nearly everywhere, in some subvariety or other of *Truncatulina lobatula.* The orbicular, concentric, plano-convex *Pl. mediterranensis* (*vulgaris*) is a later form; and its annular growth indicates a morphological position higher than that of its simply coiled allies.

Pulvinulina repanda (proper) is represented in the Chalk of Maestricht, but in none of the other Cretaceous beds. It is rare in the Tertiaries of our Table (occurring only in the Pliocene), but is scattered throughout the Atlantic. *P. auricula* existed in the Nummulitic sea, abounded in the mid-Tertiary times, and, living now, is abundant in some places; but it is wanting in the Chalk. *P. Menardii,* however, was one of the early representatives of the genus. In New Jersey (North America) it occurs in the Greensand. With us it begins with the White Chalk, and has continued with increased prolificness till now. *P. Schreibersii* occurs sporadically in the Greensand of New Jersey, the Chalk-formations of Eastern Europe, the

Upper Chalk of Western Europe, the Tertiary beds, and at the present day in the Atlantic; but it has not been found in the Lower Cretaceous rocks of Europe, though representatives of it (*P. Karsteni*, &c.) are not wanting in some of the Secondary formations. *P. elegans*, another old (Secondary) form, reached a high stage of growth and abundance in the sea that deposited the Gault of England and Europe, and has continued since.

Discorbina has presented no fossil form older than the Upper Chalk (Maestricht). Since the Cretaceous period it has abounded profusely in the Paris Tertiaries, and in many other localities since; and it still flourishes.

Rotalia is found in the Gault; but it seems to have flourished more abundantly in seas of later periods, and is prolific now in the Atlantic and elsewhere.

Of the other *Rotalinæ*, we have not sufficient data for correct observation in the line of research we have here pursued; except that we may note the isolated occurrence of *Cymbalopora* at Maestricht, and its apparent absence until the Miocene period, the absence of *Calcarina* and of *Orbitoides* before the Chalk, and, on the other hand, the persistence of *Tinoporus* and *Patellina* through the Cretaceous and Tertiary to the present age.

With the Rotalinæ, as with *Globigerina* (of which we intend to treat before long), the chief distinction between the Cretaceous and existing groups is in the progressively increased number of modifications, and among them the incoming of important variations, though few of them are of generic, or even specific, value,—a distinction strong enough, when supported by other known geological and palæontological considerations, to mark the impropriety of calling the Atlantic ooze "Chalk," except in the sense of a calcareous rock of marine organic origin. That its geological status should not be spoken of in this vague halobiolithological * sense, the painstaking and thoughtful Ehrenberg long ago warned us. He says:—"In consequence of the mass-building Infusoria and Polythalamia [Diatoms, Polycystines, and Foraminifers], the Secondary formations can now no longer be distinguished from the Tertiary; and, in accordance with what has been above stated, masses of rock might be formed even at the present time in the ocean, and be raised by volcanic power above the surface, the great mass of which would, as to its constituents, perfectly resemble the Chalk. *Thus, then, the Chalk remains still to be distinguished as a geological formation, but no longer as a species of rock by its organic contents.*" 'Taylor's Scientific Memoirs,' vol. iii. 1843, p. 367, § 10; 'Edinb. New Phil. Journ.' vol. xxxiv. 1843, p. 260; Abhandl. Berl. Akad. für 1839, p. 164, 4to, 1841.

To render our synoptical study of the Rotalinæ more complete, we propose to compare the oldest forms on some future occasion; and, for the present, we offer, in a Supplement to this paper, a critical examination and revised nomenclature of such Tertiary Rotalinæ as have been figured and described by Reuss, Bornemann, Karrer, and other palæontologists, and are not included in the foregoing lists.

* "Halobiolith" (Ehrenberg) is a stratum of marine organic origin.

The Range of Recent, Tertiary, and Cretaceous Rotalinæ.

	Pacific Ocean.	Atlantic Ocean.							Tertiary.					Cretaceous.										
									Upper.	*Middle.*	*Lower.*			Upper Chalk.	White Chalk.	Chalk formations.	Westphalian Chalk formations.			Chalk-marl.	Gault.	Green-sand.	Green-sand.	Chalk.
	South America.	South America.	Abrolhos Bank.	Tropical Atlantic.	Cuba.	Canaries.	North Atlantic.	Arctic.	Crag.	Vienna Basin.	London Clay.	Paris Tertiaries.	Kressenberg.	Maestricht, Rügen, Möen, Mecklenburg.	England and France.	Eastern Europe.	Upper.	Middle.	Lower.	Kent.	Germany and Kent.	Warminster and Haldon.	New Jersey.	North America.
Planorbulina ...	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Conical	...	...	**	*	*	...	**	...	*	**	*	...	**	**	**	*	...	*	*	*	*	*	*	
Nautiloid ...	...	*	*	...	...	...	*	*	...	**	*	*N	**	**	**	**	*	*	...	*	**	*	*	*
Plano-convex	*	*	*	*	**	**	**	*	*	**	*	*	*	**	**	**	*	*	...	...	**	*	**	
Pulvinulina......	†	†	†	†	†	†	†	†	†	†	†	...	†	†	†	†	†	†	...	†	†	†	†	
repanda	...	...	*	...	*	...	*	*	*	...	...	...	...	*										
auricula	*	...	...	...	*	*	...	...	*	**	...	*												
Menardii ...	...	...	**	**	*	**	**	*	...	...	*	...	**	*	**	*	*	*	...	*	...	...	*	
Schreibersii	*	*	*	...	...	...	*	*	*	*	...	...	...	*	...	*	...	...	...	...	...	...	*	
elegans	...	...	*	*	...	*	*	...	...	*	*	...	...	*	...	*	...	...	...	...	**	*		
Spirillina.........	...	...	...	...	...	...	*	*	*	...	...	*												
Discorbina	**	**	*	...	**	*	**	**	*	**	...	**	*	*										
Cymbalopora ...	...	...	*	...	**	...	...	...	...	*	...	...	...	*										
Rotalia............	*	*	...	...	**	*	**	...	*	*	*	*	*	*	**	**	*	...	...	...	*			
Calcarina.........	...	...	...	...	*	...	...	...	*	*	...	*	...	*	*									
Patellina.........	...	...	...	...	...	...	*	*	...	...	...	*	...	...	?	...	...	...	...	...	...	**		
Tinoporus.........	...	...	...	...	...	...	*	...	*	...	...	*	...	?	**	*	?	...	...	**	...	?		
Orbitoides	...	...	...	...	...	...	...	...	...	*M	...	*S	**	*	*S									

M = elsewhere in the Miocene. N = in the Eocene from Normandy. S = in the south of France.

Supplement.

In the foregoing paper we have compared side by side several described sets of *Rotalinæ* from the Cretaceous and Tertiary rocks, and from the present seas. We know how imperfect the materials for this critical collocation really are, and that the sketch view we get of them in the foregoing Tables is but a glimpse into a wide and unexhausted region. Numerous as the forms are that we have catalogued in their zoological order, for comparison by the naturalist, and fertile as they are in suggestions as to range and relative persistence, we do not forget the wholesome caution to Rhizopodists clearly and forcibly given by Prof. W. C. Williamson years ago, when treating of the then new and striking researches of Ehrenberg and D'Orbigny:—"We must not cloud the evidence afforded by the higher animals with that derivable from beings so much lower in the scale of organization, and which, as a whole, are so far removed from the influence of external agencies. The study is at once so novel and so fascinating that all who pursue it, impressed by its singular interest, are in danger of being allured by it beyond the bounds of caution,—a tendency which is ever promoted by the announcement of comprehensive hypotheses and splendid novelties."—'Microscop. Objects found in the Mud of the Levant,' p. 126. *Memoirs Manchester Lit. & Phil. Soc.* vol. viii. 1847.

To make our subject as clear as known facts can help us to make it, we here subjoin further lists of local groups of *Rotalinæ*, both Recent and Tertiary, prepared, on the same system of nomenclature, for rigid comparison with those in the body of this paper. From a study of these additional catalogues it will be found, as with the others, that, for the most part, numerous slight varietal differences, local and mainly recognizable in the *facies* of the group—indeed, only to be brought out by good drawings, and scarcely describable, —are important elements in the successional diversity that really obtains among the Foraminifera. These slight, but important, shades of difference give rise to great multiplicity of names. This is a trouble which we have endeavoured to deal with judiciously in all our lists, basing our nomenclature on the principles laid down in our memoirs in the 'Ann. Nat. Hist.,' in the 'Phil. Trans.' vol. clv., and in Carpenter's 'Introd. Foram.' 1862.

§ 1.—Recent Foraminifera.

I. In further illustration of the Foraminiferal fauna of the Pacific Ocean (see list, p. 115), we here offer a corrected list of the Foraminifera found by Mr. G. D. Macdonald among the Fiji Islands. See *Ann. Nat. Hist.* ser. 2, vol. xx. pp. 193 &c., 1857.

Pl. 5. f. 1 & 2. Doubtful.	From 1020 fathoms.	
f. 3–5. Polycystina.		
f. 6. Uvigerina pygmæa, *D'Orb.*, dimorphous variety.		From 440 fathoms.
f. 7–10. Lagena globosa *et* marginata (*Montagu*), Entosolenian,		

Pl. 5.	f. 11–14.	Globigerina bulloides, *D'O.*	From 1020 fathoms.
	f. 15.	Planulina * ?	
	f. 16.	Cymbalopora * Poeyi (*D'O.*).	
	f. 17.	Discorbina * globularis ? (*D'O.*), young.	
	f. 18, 19.	Nonionina umbilicatula (*Montagu*).	
	f. 20.	Discorbina * globularis ? (*D'O.*).	
Pl. 6.	f. 21.	Uvigerina pygmæa (*D'O.*), aculeate variety.	
	f. 22.	Verneuilina pygmæa (*Egger*).	
	f. 23.	Virgulina Schreibersii, *Czjzek*.	
	f. 24.	V. Schreibersii, irregular and dwarf.	
	f. 25.	Discorbina * Berthelotiana (*D'O.*).	
	f. 26.	Textilaria pygmæa (*D'O.*), *vel* Bolivina punctata, *D'O.*	
	f. 27.	Bolivina punctata, *D'O.*, with an aculeate base.	
	f. 28.	Spiroloculina planulata (*Lamk.*).	From 440 fathoms.
	f. 29.	Quinqueloculina seminulum (*Lin.*), young.	
	f. 30.	Triloculina oblonga (*Montagu*).	
	f. 31, 33.	Calcarina * Spengleri (*Gmel.*), var.	In shallow water.
	f. 32.	Described as a lenticular body, like a *Nummulina.*	

II. As an example of a Rotaline group from the Indian Ocean, we produce the following from Dr. C. Schwager's Monograph "Foraminiferen von Kar-Nicobar," *Novara Expedition*, geol. Theil, vol. ii.:—

P. 258, pl. 7.	f. 105, 107.	Anomalina Wüllerstorfi, *Schw.*	*Planorbulina* between *Pl. Ungeriana* and *Pl. ariminensis.*
P. 260,	f. 108.	Anomalina cicatricosa, *Schw.*	*Planorbulina vulgaris*, young, with some exogenous ramified ornament.
P. 257,	f. 106.	Discorbina saccharina, *Schw.*	*Pulvinulina Menardii.*
P. 262,	f. 109.	Rotalia flosculiformis, *Schw.*	*Pulv. elegans*, smooth var.
P. 259,	f. 111.	Anomalina bengalensis, *Schw.*	*Pulv.elegans*,var.*caracolla.*
P. 263,	f. 110.	Rotalia nitidula, *Schw.*	*Rotalia Soldanii*, D'O.
P. 261,	f. 114.	Calcarina nicobarensis, *Schw.*	*Calcarina Spengleri.*

§ 2.—The Tertiary Faunas, as represented by *Rotalinæ* described and figured by our continental fellow-workmen, in addition to the few selected for Table II. (p. 123), are here given in the order of publication, with corrected nomenclature.

I. F. A. Roemer. 'Die Cephalopoden des Nord-Deutschen tertiären Meersandes.' *Neues Jahrb. f. Min. &c.*, 1838, pp. 381–394.

P. 388, pl. 3.	f. 45.	Rotalia subtortuosa †, *v. Münst.*	*Discorbina.*
	f. 46.	R. depressa, *v. M.*	——.
	f. 47.	R. trochus, *v. M.*	—— ?
	f. 48.	R. mammillata, *v. M.*	—— ?
	f. 49.	R. impressa, *Rœm.*	—— ?
	f. 50.	R. intermedia, *v. M.*	*Planorbulina.*
	f. 51.	R. conica, *R.*	——.
	f. 52.	R. discus, *R.*	——.
	f. 53.	R. parvispira, *R.*	——.
P. 389,	f. 54.	R. propinqua, *v. M.*	——.
	f. 55.	Truncatulina punctata, *R.*	—— (*Truncatulina*).
	f. 56.	T. communis, *R.*	—— (*Truncatulina*).
P. 390,	f. 58.	Planulina osnabrugensis, *v. M.*	—— (*Planulina*).
	f. 59.	Planorbulina difformis, *v. M.*	—— *mediterranensis.*
P. 391,	f. 60.	Anomalina elliptica, *v. M.*	—— (*Anomalina*).

* These are *Rotalinæ.*

† These figures are not sufficiently good to serve as exact criteria for species. Some, however, have been refigured by Reuss.

II. A. E. Reuss. 'Ueber die fossilen Foraminiferen und Entomostraceen der Septarienthone der Umgegend von Berlin.' *Zeitschr. deutsch. geol. Gesellsch.*, vol. iii. 1851, pp. 49–92, plates 3–7.

Pl. 5. f. 34.	Rotalina Girardana, *Rss.*	*Rotalia Soldanii*, D'O.
f. 35.	R. umbonata, *Rss.*	*Pulvinulina* near *P. Menardii.*
f. 36.	R. granosa, *Rss.*	*Planorbulina Ungeriana* (D'O.).
f. 37.	R. contraria, *Rss.*	*Pulvinulina auricula* (F. & M.).
f. 38.	R. bulimoides, *Rss.* (not Rotaline).	*Bulimina elegantissima*, D'O.

III. A. E. Reuss. 'Beiträge zur Charakteristik der Tertiärschichten des nördlichen und mittleren Deutschlands.' *Sitzungsb. Akad. Wiss. Wien*, vol. xviii. pp. 197 &c., 1855.

P. 240, pl. 4.	f. 52.	Rotalia Rœmeri, *Rss.* =*Planorbulina Ungeriana* (D'O.).
P. 241,	f. 53.	R. propinqua, *Rss.* =*Planorbulina Haidingerii* (D'O.).
P. 242, pl. 5.	f. 54.	R. stellata, *Rss.* =*Calcarina armata* (D'O.).
	f. 55.	R. trochus, *v. M.* =*Pulvinulina trochus* (v. M.).
	f. 56.	Truncatulina communis, *Rœm.* =*Truncatulina lobatula.*
P. 243,	f. 57.	Rosalina crenata, *Rss.* =*Planorbulina* (between *ammonoides* and *Ungeriana*).
	f. 58.	R. osnabrugensis, *v.M.* (? Planulina Osnabrugensis, *v.M.*). =*Pl.* (*Planulina*) *ariminensis*, varying towards *Pl. ammonoides.*
P. 244,	f. 59.	Anomalina subæqualis, *Rss.* =*Pl. ammonoides* (Rss.).
	f. 60.	A. tenuissima, *Rss.* =A thin subvariety of *A. complanata*, D'O.

IV. Bornemann. 'Die mikroscopische Fauna des Septarienthones von Hermsdorf bei Berlin.' *Zeitschr. deutsch. geol. Gesellsch.* vol. vii. 1855, pp. 307–371, plates 12–21.

Pl. 16. f. 5.	Rotalina Ungeriana, *D'O.*	*Planorbulina.*
f. 6.	R. Partschiana, *D'O.*, var.	*Pulvinulina.*
f. 7.	R. Akneriana, *D'O.*, var.	*Planorbulina.*
f. 8.	R. tæniata, *Born.*	*Rotalia* near *R. Soldanii.*

V. J. G. Egger. 'Die Foraminiferen der Miocän-Schichten bei Ortenburg in Nieder-Bayern.' In *Neues Jahrb. für Min. &c.*, 1857.

Planorbulina farcta (type).

Conical.	P. 13, pl. 3. f. 8–10.	Rotalina Dutemplei, *D'O.*	*Planorbulinæ*, varying from *Pl. Dutemplei* to *Pl. Haidingerii* and *Pl. Akneriana*, D'O.
	P. 12, pl. 5. f. 21–23.	R. kalembergensis, *D'O.*	
	P. 15, pl. 4. f. 8–10.	R. anomphala, *Egger.*	
	P. 14, pl. 6. f. 1–3.	R. orthorapha, *Egger.*	
	P. 15, pl. 3. f. 14–17.	R. propinqua, *Reuss.*	
	P. 16, pl. 4. f. 4–7.	R. discigera, *Egger.*	
	P. 19, pl. 6. f. 12–14.	R. patella, *Egger.*	
Nautiloid.	P. 17, pl. 5. f. 4–6.	Rotalina cryptomphala, *Rss.* Between *Pl. ammonoides* and *Tr. lobatula.*	
	P. 18, pl. 6. f. 4–6.	Rosalina simplex, *D'O.* *Anomalina.*	
	P. 20, pl. 5. f. 14–16.	Truncatulina tumescens, *Egger.* *Planorb. tuberosa*, depressed var.	
	P. 20, pl. 5. f. 10–13.	?Anomalina anomala, *Egger.* Anomaline, with irregular chambers.	
Plano-convex.	P. 19, pl. 5. f. 1–3.	Truncatulina lobatula (*W. & J.*).	
	P. 21, pl. 6. f. 15–17.	Planorbulina truncata, *Egger.* *Truncatulina variabilis*, D'O.	

PULVINULA REPANDA (type).

P. 13, pl. 3. f. 5–7. Rotalina Brongniartii, *D'O.* Subvariety of *Pulvinulina auricula* (F. & M.).

SPIRILLINA VIVIPARA (type).

P. 50, pl. 6. f. 7, 8. ? Cyclolina impressa, *Egger.* =*Spirillina vivipara*, Ehr.

DISCORBINA TURBO (type).

P. 14, pl. 3. f. 11–13. Rotalina Haidingerii, *D'O.* (Non *Pl. Haidingerii.*) *Discorbina* between *globularis* and *turbo.*

P. 16, pl. 4. f. 1–3. R. semiporata, *Egger.* =*Discorbina globularis*, D'O.

P. 22, pl. 7, f. 8–10. Asterigerina planorbis, *D'O.* =*Discorbina planorbis* (*rosacea*) (D'O.).

ROTALIA BECCARII (type).

P. 17, pl. 4. f. 11–13. Rosalina viennensis, *D'O.* =*Rotalia Beccarii*, var.

CALCARINA SPENGLERI (type).

P. 13, pl. 3. f. 1–4. Rotalina aculeata, *D' O.* } *Calcarina Spengleri*, var.
P. 18, pl. 4. f. 14–16. Rosalina horrida, *Egger.* }

VI. A. E. REUSS. 'Beiträge zur Kenntniss der tertiären Foraminiferen-Fauna. Zweite Folge. I. Die Foraminiferen des Septarien-Thones von Offenbach.' *Sitzungsb. Akad. Wiss. Wien*, vol. xlviii. 1863, pp. 36–61.

P. 59. Rotalia Girardana, *Rss.* =*Rotalia Soldanii*, D'O.
R. Partschiana, *D' O.* =*Pulvinulina Partschiana* (D'O.).
P. 60. R. umbonata, *Rss.* =*Pulv. umbonata* (Rss.).
R. Ungeriana, *D' O.* } =*Planorbulina Ungeriana* (D'O.).
R. granosa, *Rss.* }
P. 61. Truncatulina variabilis (?), *D' O.* =*Pl.* (*Truncatulina*) *variabilis*, D'O.

——. II. 'Die Foraminiferen des Septarienthones von Kreuznach.' *Op. cit.* pp. 61–71.

P. 68. Rotalia Girardana, *Rss.* =*Rotalia Soldanii*, D'O.
Pl. 8. f. 97. Rosalina Weinkauffi, *Rss.* =*Planorbulina* (*Anomalina*) *complanata* (D'O.).

VII. A. E. REUSS. 'Les Foraminifères du crag d'Anvers.' *Bullet. Acad. Roy. Sc. Belg.* vol. xv. 1863, pp. 137–162. (See above, p. 120.)

P. 154. Rotalia Brongniartii, *D' O.* *Pulvinulina.*
—— cristellaroides, *Rss.*, pl. 3. f. 44. =*Pulv. Brongniartii*, subvar.
P. 155. —— kalembergensis, *D' O.* *Planorbulina.*
—— orbicularis, *D' O.* *Rotalia.*
—— tenuimargo, *Rss.* *Planorbulina.*
Truncatulina varians, *Rss.* =*Pl. Ungeriana*, subvar.
—— oblongata, *Rss.*, pl. 3. f. 45. Neat *Tr. lobatula.*
Rosalina, sp. = ?

VIII. A. E. REUSS. 'Zur Fauna des deutschen Oberoligocäns.'

Erste Abtheilung. *Sitzungsb. Akad. Wiss. Wien*, vol. l. part 1, 1864. (A useful Table accompanies this memoir.)

P. 41.	Rotalia Dutemplei, *D'O.* *Planorbulina Dutemplei* (D'O.).
	R. Rœmeri, *Rss.* *Pl. Ungeriana* (D'O.).
	R. umbonata, *Rss.* *Pulvinulina umbonata* (Rss.).
	R. propinqua, *Rss.* *Planorbulina Haidingerii* (D'O.).
	R. kalembergensis, *D'O.* *Pl. kalembergensis* (D'O.).
	R. Boueana, *D'O.* *Pulvinulina Boueana* (D'O.), near *pulchella* (D'O.).
P. 42.	R. Brongniartii, *D'O.* *Pulv. Brongniartii* (D'O.).
	R. Haueri, *D'O.* *Pulv. Haueri* (D'O.), near *auricula* (F.& M.).
	R. trochus, *v. M.* *Pulv. trochus* (v. M.).
	R. stellata, *Rss.* *Calcarina armata* (D'O.).
	Asterigerina planorbis, *D'O.* *Discorbina.*
	Rosalina obtusa, *D'O.* *Discorbina*, near *globularis* (D'O.).
P. 43.	R. osnabrugensis, *v. M.* *Planorbulina osnabrugensis* (v. M.).
	Anomalina tenuissima, *Rss.* *Pl.* (*Anom.*) *tenuissima*, Rss.
	A. subæqualis, *Rss.* *Pl. ammonoides* (Rss.).
	Truncatulina communis, *Rœm.* *Pl.* (*Tr.*) *lobatula* (W. & J.).
	T. lobatula, *D'O.* *Pl.* (*Tr.*) *lobatula* (W. & J.).
Pl. 5. f. 6.	T. tenella, *Rss.* Subvariety of *T. lobatula* (W. & J.).

IX. A. E. Reuss. 'Die fossilen Foraminiferen, Anthozoen, und Bryozoen von Oberburg in Steiermark. Ein Beitrag zur Fauna der oberen Nummulitenschichten.' *Denkschr. Akad. Wiss. Wien*, vol. xxiii. 1864.

P. 9, pl. 1. f. 14.	Rotalia formosa, *Rss.* (Non *Rotalia.*) *Discorbina?*
P. 10.	Rosalina obtusa, *D'O.* *Discorbina obtusa* (D'O.).
f. 15.	Truncatulina variabilis, *D'O.*

X. A. E. Reuss. 'Die Foraminiferen, Anthozoen, und Bryozoen des deutschen Septarienthones. Ein Beitrag zur Fauna mitteloligocänen Tertiärschichten.' *Denkschr. Akad. Wiss. Wien*, vol. xxv. 1866.

P. 159.	Truncatulina variabilis, *D'O.* *Planorbulina* (*Truncatulina*).
	T. communis, *Rœm.* *Pl.* (*Tr.*) *lobatula.*
	T. Boueana, *D'O.* *Pl.* (*Tr.*) *lobatula*; neat.
	T. austriaca (*D'O.*). *Pl.* (*Anomalina*) *austriaca*, D'O.
P. 160.	T. Weinkauffi, *Rss.* *Pl.* (*Anom.*) *complanata*, D'O.
	T. Akneriana, *D'O.* *Pl. Akneriana* (D'O.).
Pl. 4. f. 15.	T. lucida, *Rss.* *Pl.* near *Pl. Ungeriana* (D'O.).
	T. Rœmeri, *Rss.* *Pl. Ungeriana* (D'O.).
f. 16.	T. Dutemplei (*D'O.*). *Pl. Dutemplei* (D'O.).
P. 161.	T. Ungeriana (*D'O.*). *Pl. Ungeriana* (D'O.).
	T. granosa, *Rss.* *Pl. Ungeriana* (D'O.).
	Discorbina marginata, *Rss.* *Globigerina marginata* (Rss.).
	D. planorbis (*D'O.*). *D. rosacea* (D'O.).
f. 14.	Pulvinulina Boueana (*D'O.*). *Pulvinulina* near *P. pulchella.*
	P. Partschiana (*D'O.*). *Pulv.* near *P. elegans.*
P. 162.	P. umbonata, *Rss.* *Pulv.* near *P. Menardii.*
	P. contraria, *Rss.* *Pulv.* near *P. auricula.*
	Siphonina reticulata (*Cžjž.*). *Planorbulina* (*Siphonina*).
	Rotalia bulimoides, *Rss.* *Bulimina elegantissima*, D'O.
P. 163.	R. Girardana, *Rss.* *R. Soldanii*, D'O.
	R. tæniata, *Born.* *Rotalia* near *R. Soldanii.*
f. 17.	R. grata, *Rss.* *Planorbulina* near *Pl. Haidingerii.*
(Not figrd.)	R. polita, *Rss.* Described as being near *R. Beccarii.*

XI. A. E. Reuss. 'Die fossile Fauna der Steinsalzablagerung von Wieliczka in Galizien.' *Sitzungsb. Akad. Wiss. Wien*, vol. lv. part 1, 1867. (This memoir contains a good Table of the distribution of the Oligocene and Miocene Foraminifera.)

P. 83.		Truncatulina lobatula (*W. & J.*).
P. 84.		T. Ungeriana (*D'O.*). T. Dutemplei (*D'O.*). T. Haidingerii (*D'O.*). } *Planorbulinæ.*
P. 85.		Discorbina planorbis (*D'O.*). Near *D. rosacea* (D'O.).
	Pl. 5. f. 1.	D. stellata, *Rss.* } Near *D. valvulata* (D'O.).
	f. 2.	D. squamula, *Rss.* } Near *D. valvulata* (D'O.).
P. 86.		D. obtusa (*D'O.*). Near *D. globularis* (D'O.).
	Pl. 4. f. 13.	D. platyomphala (*Rss.*). Near *D. parisiensis* (D'O.).
		D. complanata (*D'O.*). Near *D. elegans* (D'O.).
		D. cryptomphala, *Rss.* *Planorbulina*, near *Pl. Akneriana* (D'O.).
		D. arcuata, *Rss.* *Discorbina* near *D. trochidiformis* (Lamarck).
P. 87.		Pulvinulina Haueri (*D'O.*). Near *P. auricula* (F. & M.).
	Pl. 5. f. 3.	P. cordiformis (*Costa*). Near *P. auricula* (F. & M.).
		P. Boueana (*D'O.*). Near *P. pulchella* (D'O.).
		P. kalembergensis (*D'O.*) *Planorbulina kalembergensis* (D'O.).
P. 88.		P. nana (*Rss.*). *Discorbina* near *D. trochidiformis* (Lamarck).
		P. Partschiana (*D'O.*). Near *P. elegans* (D'O.).
		Rotalia Beccarii (*Linn.*).
P. 89.		R. Soldanii, *D'O.*

XII. F. Karrer. 'Die miocene Foraminiferen-Fauna von Kostej im Banat.' *Sitzungsb. Akad. Wiss. Wien*, vol. lviii. part 1, 1868.

P. 60.		Truncatulina Schreibersii (*D'O.*). *Pulvinulina.*
		T. Haidingerii (*D'O.*). *Planorbulina.*
		T. Ungeriana (*D'O.*). *Planorbulina.*
P. 61.		T. Dutemplei (*D'O.*). *Planorbulina.*
		T. Brongniartii (*D'O.*). *Pulvinulina.*
		T. lobatula (*Walk.*). *Planorbulina* (*Truncatulina*).
		T. Boueana *D'O.* *Planorbulina* (*Truncatulina*).
		T. variolata (*D'O.*) *Planorbulina* (*Anomalina*).
		T. rotula (*D O.*). *Planorbulina* (*Planulina*).
P. 62, pl. 4. f. 13.		T. stella, *Kar.* } *Planorbulina* (*Anomalina*) *ammonoides* (Rss.), subvar.
	f. 14.	T. inæqualis, *Kar.* } *Planorbulina* (*Anomalina*) *ammonoides* (Rss.), subvar.
	f. 15.	T. flos, *Kar.* *Discorbina*, near *D. rosacea* (D'O.).
P. 63, pl. 5. f. 1.		T. laciniata, *Kar.* *Discorbina.*
	f. 2.	T. papillata, *Kar.* *Discorbina.*
P. 64, pl. 5. f. 3.		T. regularis, *Kar.* *Discorbina.*
		Discorbina planorbis (*D'O.*). *Discorbina.*
		D. obtusa (*D'O.*). *Discorbina.*
P. 65.		D. complanata (*D'O.*). *Discorbina.*
		D. squamula, *Rss.* *Discorbina.*
		D. platyomphala, *Rss.* *Discorbina.*
	Pl. 5. f. 4.	D. turris, *Kar.* *Discorbina.*
	f. 5.	D. semiorbis, *Kar.* *Discorbina*, near *D. turbo* (D'O.).
P. 66.		Pulvinulina Haueri (*D'O.*). *Pulvinulina.*
		P. Boueana (*D'O.*). *Pulvinulina.*
		P. kalembergensis (*D'O.*). *Planorbulina.*
		P. Partschiana (*D'O.*). *Pulvinulina.*

P. 66. P. perforata*, *Kar.* *Planorbulina* near to *Pl. Haidingerii* (D'O.).
P. 67, pl. 5. f. 6. P. erinacea, *Kar.* *Pulvinulina* related to *P. excavata* (D'O.) of the *auricula* group.
Rotalia Beccarii (*Linn.*). *Rotalia.*
R. simplex (*D' O.*). *Planorbulina.*
R. aculeata, *D' O.* *Calcarina.*
P. 68. R. Girardana, *Rss.* *Rotalia Soldanii,* D'O.
R. spinimargo, *Rss.* *Pulvinulina.*
R. tuberosa, *Kar.* *Rotalia Schrœteriana,* P. & J.
R. granulosa, *Kar.* *Cymbalopora granulosa* (Kar.).
P. 69, pl. 5. f. 7. R. præcincta, *Kar.* *Planorbulina Haidingerii* (D'O.), subv.

XIII. A. E. Reuss. 'Zur fossilen Fauna der Oligocänschichten von Gaas bei Dax.' *Sitzungsb. Akad. Wiss. Wien,* vol. lix. 1 Abth. 1869.

P. 15. Planorbulina mediterranea, *D' O.*
—— variabilis (*D' O.*).
P. 16. Truncatulina falcata, *Rss.*, pl. 2. f. 1.
—— insignis, *Rss.*, pl. 2. f. 2.
P. 17. —— Haidingerii (*D' O.*). *Planorbulina.*
Discorbina obtusa (*D' O.*).
—— crenulata, *Rss.*, pl. 2. f. 3.
P. 18. —— stellata, *Rss.*, pl. 2. f. 4. *Calcarina armata* (D'O.).
Pulvinulina prominens, *Rss.*, pl. 3. f. 2. Near *P. elegans* (D'O.).
P. 19. —— formosa, *Rss.*, pl. 3. f. 1. Near *P. Menardii* (D'O.).
—— grandis, *Rss.*, not figured.
Rotalia rimosa, *Rss.*, pl. 2. f. 5. *Calcarina armata,* feeble var.

XIV. A. E. Reuss. 'Die Foraminiferen des Septarienthones von Pietzpuhl.' *Sitzungsb. Akad. Wiss. Wien,* vol. lxii. part 1, 1870. (This is avowedly not an exhaustive list.)

P. 36. Truncatulina variabilis, *D' O.*
T. Akneriana (*D' O.*). }
T. Ungeriana (*D' O.*). } *Planorbulinæ.*
T. granosa, *Rss.* }
Pulvinulina Partschiana (*D' O.*). Of the *elegans* group.
P. umbonata, *Rss.* Of the *Menardii* group.
P. contraria, *Rss.* }
P. Haueri (*D' O.*). } Of the *auricula* group.
Siphonina reticulata (*Cžjžek*). *Planorbulina* (*Siphonina*).
P. 37. Rotalia bulimoides, *Rss.* (Non *Rotalia.*) *Bulimina elegantissima,* D'O.
R. Girardana, *Rss.* =*R. Soldanii,* D'O.

Discussion.

The President suggested the possibility of some of the minute Foraminifera being transported fossils derived from earlier beds than those in which they are now found.

Dr. Carpenter observed that the mode of examination to be adopted with Foraminifera was different in character from that which was applicable to higher organisms. The range in variation was so great that a comparatively imperfect examination of Nummulites had sufficed to make M. d'Archiac reduce the number of species by one half; and all the speaker's subsequent studies had impressed upon him the variety in form and in sculpturing of surface on individuals of the

* Found also in Tertiary sands at Orakei Bay, New Zealand. 'Novara-Expedition, Neu-Seeland; Abth. Paläontologie,' p. 81, pl. 16. See also, for Critical Notes, Geol. Mag. 1864, no. 2, p. 74.

same species. When out of some thousands of specimens of *Operculina*, say, a dozen pronounced forms had been selected, such as by themselves seemed well marked and distinct, it might turn out that after all there was but one species present, with intermediate varieties connecting all these different forms. He thought the same held good with *Rotalinæ*, and that there were osculant forms which might connect, not only the species, but even the genera into which they had been subdivided. This fact had an important bearing on their genetic succession, especially as it appeared that some of the best-marked types were due to the conditions under which they lived.

The temperature in tropical seas differed in accordance with the depth so much, that when 2000 fathoms were reached a degree of cold was attained such as was to be found in high latitudes; and in consequence the deep-sea forms in tropical latitudes assumed the dwarfed character of those in shallower seas and nearer the Pole. He suggested caution in drawing inferences from forms so subject to modification, both spontaneous and due to the depth of the sea, especially as connected with abundance of food.

Prof. RAMSAY remarked that geologists would be pleased to find Foraminifera exhibiting, like other organisms, changes in some degree connected with the lapse of time. These low forms, however, could hardly afford criteria for judging of the age of geological formations, while at the same time such ample means were afforded by the higher organisms for coming to a conclusion. He cited, for instance, the Cephalopoda as proving how different were the more important forms of marine life in Cretaceous times from those of the present day. He thought that no one who had thoroughly studied the forms of ancient life would be led to ignore the differences they presented, as a whole, from those now existing.

Mr. SEELEY, Dr. MURIE, and Mr. HICKS also made some remarks on the paper.

Prof. JONES, in reply, observed that the question of whether the Foraminifera in a given bed were derived or not was to be solved partly by their condition and partly by their relative proportions, and that in most cases sufficient data existed on which to found a judgment. He agreed with Dr. Carpenter as to the existence of extreme modifications; and it had been his object to ignore such as seemed due to ordinary and local causes, and to group the forms in accordance with certain characteristics. Whether the classification was right or wrong, it was necessary, for the sake of increasing knowledge, that fossils of this kind should be arranged in groups; and whether these were to be regarded as truly generic was a minor consideration. In forming their types and subtypes the authors had carefully avoided minor differences; and they thought that the modifications which were capable of being substantiated were significant of a great lapse of time. A variation once established never returned completely to the original type. In *Globigerina*, he stated that there were in Cretaceous times 8 forms, in Tertiary 12, at the present time 14; and these modifications he regarded as equivalent to the specific changes in higher animals.

2. *On the* Infralias *in* Yorkshire. By the Rev. J. F. Blake, M.A., F.G.S. *With an* Appendix *on some* Bivalve Entomostraca. By Prof. T. Rupert Jones, F.G.S.

Comparatively little attention has been paid to the Lias of Yorkshire for some time past; and consequently it is behind the Lias of other parts as to our knowledge of it. This is especially the case with the lowest beds—the zones of *Ammonites angulatus* and *Am. planorbis*—constituting the so-called Infralias, whose presence has as yet been scarcely even recognized. It has long been known that *Am. angulatus* occurs at Redcar, under the name of *A. Redcarensis*; and blocks of stone containing *Am. planorbis* (syn. *erugatus*) are thrown up on the coast; but no section, or list of fossils, has as yet been given of the beds.

In the present paper I hope chiefly to describe some remarkable sections at Cliff, near Market-Weighton, where the Infralias is well exposed, and the fauna it contains is large and interesting. But, while I describe this as the Infralias of Yorkshire, I must express my opinion that it does not form part of the typical Yorkshire basin. On glancing at a geological map of this part of England, it will appear probable that there has existed a ridge in Carboniferous-Limestone times, stretching west from a little south of Flamborough Head, which has separated the coal-basin of South Yorkshire from that of Durham, and made a gap in the overlying Permian rocks; and though the New Red Sandstone does not appear to be affected by it, all the overlying Jurassic beds are bent round in a curve on its north side, and to the south appear again as the thin end of a series stretching right across England. The beds to the north form the typical Yorkshire basin, while those at Cliff form part of the thin end of the wider-reaching series. Good sections of all the Infralias beds in the typical Yorkshire basin are still a desideratum, which I am unable to supply; but when they are discovered, it must be with the Cliff beds that we first compare them. The nearest beds with which to compare these latter, are those at Marton, near Gainsborough, the list of fossils from which, as given by Mr. Ralph Tate in Quart. Journ. Geol. Soc. vol. xxiii. 1867, proves them to contain a somewhat similar fauna, as will be seen in the sequel.

The Infralias beds of Cliff have been briefly described or, rather, noticed by the Rev. W. Norwood, in the 'Geologist,' vol. i.; but though he recognized their true age, the fossils contained in the beds were so cursorily examined that but little attention has been paid to his paper. Prof. Phillips also mentions them, but only to state their existence.

About three miles from Market-Weighton, on the road to North Cave, at the villages of North and South Cliff, and near the farm of Bielbecks (whose mammalian treasures were described by the Rev. W. V. Harcourt in the 'Phil. Mag.'), are a series of pits opened to extract the Lias clay for marling the adjoining sandy flats.

In the first of these pits (which for want of any local name must be called "Pit No. 1") we have the following section:—

Section in Pit No. 1.

Lithology.	Observations.
Surface soil.	
1. Sandy clay, 3 ft.	
2. Bed of stone, 6 in.	Very fossiliferous. *Am. angulatus.*
3. Sandy clay, 1 ft.	
4. Rubbly stone, 10 in.	Very fossiliferous. *Am. angulatus.*
5. Clay, sandy at top, blue at the bottom, extending to the base of the pit, 8 ft.	Fossils numerous, in the form of impressions. Foraminifera abundant.

In beds Nos. 1 and 3 I have found neither Foraminifera nor other fossils; but beds Nos. 2 and 4 are very rich. In fact these two beds here form the most fossiliferous zone of *Ammonites angulatus*. They are composed of rubbly irregular limestone, often crowded with fragments of shells; and from the heaps of them at the pit-side I have obtained the following fossils:—

Plesiosaurus (tooth).
Acrodus minimus (*Ag.*) (tooth).
Ammonites angulatus (*Schl.*).
—— Johnstoni (*Sow.*).
Nautilus striatus (*Sow.*).
Trochotoma striatum (*Hörn.*).
Pleurotomaria nucleus (*Terq.*).
Phasianella Morencyana (*Terq.*).
Littorina elegans (*Gldf.*).
Melania unicingulata (*Terq.*)
Turritella Dunkeri (*Terq.*).
Cerithium semele (*D' Orb.*).
Saxicava arenicola (*Terq.*).
Arcomya elongata (*Röm.* sp.).
Pleuromya galathea (*Ag.*).
—— striatula (*Ag.*)?
Pholadomya glabra (*Ag.*).
—— Fraasi (*Opp.*).
Cardinia Listeri (*Sow.*).
—— ovalis (*Stutchb.*).
—— crassiuscula (*Sow.*).
—— unioides (*Ag.*).
—— lanceolata (*Stutchb.*)?
—— Desoudini (*Terq.*).
—— Deshayesi (*Terq.*).
Astarte Guenxii (*D' Orb.*).
—— cingulata (*Terq.*).
Cardita Heberti (*Terq.*).
Unicardium cardioides (*Ph.* sp.).
Lucina ovula (*T. & P.*).
Protocardia Philippiana (*Dkr.*).
Cardium profundum (n. s.).
Cucullæa hettangiensis (*Terq.* sp.).
—— navicula (*T. & P.*).
Leda texturata (*T. & P.*).
Modiola minima (*Sow.*).
—— psilonoti (*Qu.*).
Myoconcha psilonoti (*Qu.*).
Pinna semistriata (*Terq.*).
Perna infraliasica (*Qu.*).
Avicula longiaxis (*Buckm.*).
Lima gigantea (*Sow.*).
—— punctata (*Sow.*).
—— pectinoides (*Sow.*).
—— fallax (*Chap. & Dew.*)?
—— succincta (*Schl.*).
Pecten punctatissimus (*Qu.*).
—— textilis (*Mstr.*).
Waldheimia perforata (*Piette*).
Serpula capitata (*Ph.*).
—— plicatilis (*Mstr.*).
—— socialis (*Gldf.*).
Cidaris Edwardsii (*Wr.*).
Pentacrinus psilonoti (*Qu.*).
Septastræa excavata (*From.*).

Bed No. 5 is more sandy and lighter-coloured at the top, and gradually changes to a soft laminated clay without any distinct line of demarcation. The same fossils occur throughout as indistinct impressions. They are the following:—

Ammonites Johnstoni (*Sow.*).
Cardinia, sp.
Protocardia Philippiana (*Dkr.*).
Modiola minima (*Sow.*).
Pecten æqualis (*Quenst.*).
Ostrea irregularis (*Mstr.*).
Hemipedina Tomesii (*Wr.*).

The Foraminifera are very abundant, and form a different set in the top and the bottom, Cristellarians being most numerous in the former and Polymorphines in the latter. The chief species are:—

In the top.	In the bottom.
Cristellaria acutauricularis (*F. & M.*).	Lingulina, sp.
—— crepidula, (*F. & M.*).	Polymorphina lactea (*W. & J.*).
—— varians (*Born.*).	—— gutta (*D'Orb.*).
Polymorphina, sp.	——, sp.
	Dentalina communis (*D'Orb.*).
	—— plebeia (*Rss.*).
	—— brevis (*D'Orb.*).
	——, sp.
	Nodosaria, sp.
	Marginulina lituus (*D'Orb.*).

A short distance further on we meet with another larger pit, in which is the following section:—

Section in Pit No. 2.

Lithology.	Observations.
Surface-soil 2 ft. 3 in.	
1. Rubbly stone, 1 ft. 10 in.	*Nautilus striatus.*
2. Sandy yellow clay, 2 ft.	
3. Rubbly stone, 1 ft.	*Lima gigantea.*
4. Blue clay, 5 ft. 4 in.	*Ostrea irregularis.* Gypsum.
5. Stone-bed, 6 in.	*Lima gigantea.* *Am. Johnstoni.*
6. Blue clay, 3 ft. 3 in.	
7. Irregular course of Septarian nodules	*Am. Johnstoni.* *L. gigantea.*
8. Blue clay, 3 ft. (with 7)	*Pentacrinitus psilonoti.* *Cerithium.*
9. Stone, 6 in	*Am. Johnstoni.* *Cardinia Listeri.*
10. Blue clay in layers, 10 ft. 8 in., to the base of the quarry.	

In a part of the quarry opened at a lower level are seen some oyster-bands (*Ostrea irregularis*, Mstr.), such as are seen better in the next pit.

The beds No. 1 and No. 3 of this pit evidently correspond to No. 2 and No. 4 of pit 1; and if they have yielded fewer fossils, it is probably only from being less exposed; the lower beds are decidedly less fossiliferous. In all the beds here *Am. Johnstoni* (Sow.) is the chracteristic Ammonite; and I have not detected the true *A. planorbis* in the clay beds. They are, however, full of Foraminifera and Entomostraca. The varieties are too numerous to be fully recorded here, and must await further study, with other Liassic representatives. Their chief forms, however, are:—

*Bairdia ellipsoidea (*Brady*).
*Cythere Moorei (*Brady*).
*—— Blakei (*Jones*).
*—— Terquemiana (*Jones*).
Lagena fusiformis (*Terq.*).
——, sp.
Vaginulina legumen (*L.*).
——, sp.
Dentalina communis (*D'Orb.*).
—— pauperata (*D'Orb.*).
—— plebeia (*Rss.*).
—— filiformis (*D'Orb.*).
Marginulina glabra (*D'Orb.*).
Marginulina lituus (*D'Orb.*).
—— ensis (*Rss.*).
Polymorphina bilocularis (*Terq.*).
—— lactea (*W. & J.*).
—— gutta (*D'Orb.*).
Cristellaria acutauricularis (*F. & M.*).
—— crepidula (*F. & M.*).
—— varians (*Born.*).
Planulina Bronnii (*Röm.*).
Lingulina tenera (*Born.*).
——, sp.
Nodosaria paupercula (*Rss.*).
—— lineolata (*Rss.*).

The other fossils obtained from this pit are:—

Ammonites Johnstoni (*Sow.*).
Nautilus striatus.
Trochotoma striatum (*Hörn.*).
Cerithium transversum (n. s.).
Cardinia ovalis (*Stutchb.*).
Unicardium cardioides (*Ph.*).
Modiola minima (*Sow.*).
Lima gigantea (*Sow.*).
Lima fallax (*Chap. & Dew.*).
Pecten punctatissimus (*Qu.*).
Ostrea irregularis (*Mstr.*).
Waldheimia perforata (*Piette*).
Montlivaltia Haimei (*Chap. & Dew.*).
Pentacrinus psilonoti (*Qu.*).
Serpula socialis (*Gldf.*).
—— capitata (*Ph.*).

In the oyster-bands:—

Ostrea irregularis (*Mstr.*).
Avicula fallax (*Pflücker*).
Myacites musculoides (*Schl.*).

It is in the third pit, however, that we obtain the best section of all, which, from being constantly worked, leaves all the strata well exposed. It is as follows.

Section in Pit No. 3.

Lithology.	Observations.
Surface soil, 2 ft. 3 in.	
1. Rubbly stone, 1 ft. 6 in.	*Cardinia Listeri, Ostrea irregularis, Lima gigantea, Am. Johnstoni.*
2. Rough rubbly clay, 1 ft.	
3. Rubbly stone, 8 in.	
4. Rough yellow clay, about 3 ft. ...	*Pentacrinites.*
5. Stone, 8 in.	5, 6, 7 full of small broken shells.
6. Clay, 1 ft.	
7. Stone, 1 ft. 4 in.	Wood.
8. Bluer clay, 2 ft. 2 in.	
9. Double sandy stone, 8 in.	*L. gigantea, Modiola minima.*
10. Quite blue clay, 2 ft.	*Am. Johnstoni* and *Ostrea irregularis*, and finely costated *Avicula*.
11. Sandy layer, nearly stone, broken in pieces, 3 ft. 7 in.	Oysters.
12. Blue clay, 5 ft. 6 in.	*Protocardia Philippiana, Ostrea irregularis.*
13. Stone, 5 in.	*Lima gigantea.*
14. Blue clay, 3 ft. 7 in.	Numerous small casts and fragments of Echinoderms. Tooth of *Dapedius*.
15. Stone, 10 in.	*Modiola minima.*
16. Clay containing scattered Septarian nodules, 2 ft.	*Am. Johnstoni, Hybodus minor.*
17. Stone, 5 in.	

* Kindly determined by Prof. T. R. Jones (see Appendix, p. 146).

Section in Pit No. 3 (continued).

Lithology.	Observations.
18. Blue clay with few fossils, 9 ft. ...	*Am. planorbis* (true). *Protocardia Philippiana.* *Ichthyosaurus* (vertebra).
19. Rubbly soft stone, 4 in.	
20. Rough yellow clay, 4 in.	
21. Rubb y stone, 4 in.	
22. Rough clay, 5 in.	
23. Double oyster-band..................	*Ostrea irregularis, Protocardia Philippiana, Nautilus striatus, Cucullæa hettangiensis.*
24. Clay, 2 in.	
25. Broken oyster-band, 5 in.	*Ostrea irregularis.* *Avicula fallax.*
26. Clay with light-coloured band at the top, 8 in.	
27. Rubbly stone, 2 in.	
28. Clay, 10 in.	
29. Light sandy rubbly clay, 4 in.	
30. Clay containing, about halfway down, flat layers of hard stone irregularly scattered, full of fossils, 1 ft. 6 in..................	*Protocardia Philippiana.* *Modiola minima.* *Myacites musculoides* (var. α).
31. Light sandy clay like 29, 2 ft. 6 in.	
32. Clay, 2 ft. 4 in.	
33. White, easily broken stone, 3 in.	
34. Clay, 1 ft. 8 in.	
35. Stone like 33, 3 in.	
36. Clay with layers of white clay, 6 in.	
37. Clay, 3 ft. 4 in.	
38. Whitish sandy stone, 5 in.	
39. Clay to base, about 2 ft.	

In this section there are plainly four sets of beds:—1st, from 1 to 7, in which the clays are yellowish and lie in narrow beds between narrow stone layers; 2nd, from 8 to 18, in which we have thick beds of blue clay separated by thin bands of stone; in both these sets Foraminifera abound, but suddenly cease with bed 22; 3rd, from 19 to 30, which consist of narrow alternating bands of rough clay and stone containing oyster-beds and other fossils; 4th, from 31 to the base, in which the stone layers are fissile and white, and fossils are absent or exceedingly rare.

The beds in this pit do not correspond very accurately with those in pit No. 2; but beds 1, 2, 3 appear to be equivalent in the two sections, and Nos. 10, 11, 12 in pit No. 3 to be equivalent to No. 10 in pit No. 2.

We have here, then, exposed as complete a series of Infraliassic beds as is to be found in this neighbourhood. The upper two or three beds belong to the zone of *Am. angulatus* proper, being the representatives of those which in the other pits are so fossiliferous. The beds from 4 to 22 may constitute the zone of *A. planorbis*, though that Ammonite is as yet found only in one bed; above this the beds with *Am. Johnstoni* seem a kind of intermediate zone, which must, however, be united with that of *planorbis*; and the beds to 22 are included because of the Foraminifera. Below these the beds correspond well with the series called *White Lias*, including in that the oyster-bands and the white limestone below; and enclosing, as they do, the same fauna, they must be considered the equivalents of that series.

As none of the beds have as yet proved very fossiliferous, and all the fossils (except microscopic ones) have been mentioned in connexion with their respective beds, a list of them is unnecessary; but the chief species of Foraminifera are the following:—

Lingulina tenera (*Born.*).
——, sp.
Polymorphina bilocularis (*Terq.*).
—— lactea (*W. & J.*).
—— gutta (*D' Orb.*).
——, sp.
Triloculina liasina (*Terq.*).
Textularia, sp.
Lagena fusiformis (*Terq.*).
—— sulcata (*W. & J.*).
——, sp.
Cornuspira infima (*Stutchb.*).
Webbina irregularis (*D' Orb.*).
Lituola, sp.
Dentalina pauperata (*D' Orb.*).
—— gracilis (*D' Orb.*).
—— monilis (*Rss.*).
—— communis (*D' Orb.*).
—— plebeia (*Rss.*).
—— filiformis (*D' Orb.*).
—— obliqua (*D' Orb.*).
Dentalina brevis (*D' Orb.*).
—— oblique-striata (*Rss.*).
Nodosaria lineolata (*Rss.*).
—— glans (*D' Orb.*).
—— radicula (*L.*).
—— raphanistrum (*L.*).
Marginulina lituus (*D' Orb.*).
—— raphanus (*L.*).
—— ensis (*Rss.*).
Vaginulina legumen (*L.*).
Planularia Bronnii (*Röm.*).
—— cornucopiæ (*Brady*).
—— pauperata (*P. & J.*).
Cristellaria crepidula (*F. & M.*).
—— acutauricularis (*F. & M.*).
—— cassis (*F. & M.*).
—— rotulata (*Lam.*).
Flabellina rugosa (*D' Orb.*).
Frondicularia pulchra (*Terq.*).
——, sp.

At several places on the hill-side the lower beds of pit No. 3 may be seen exposed near the road-side,—in one place the oyster-bands, in which I found *Pecten pollux* (D'Orb.), and in another, thickish blocks of white limestone with impressions of sulcated shells, probably *Myacites musculoides* (Schl.).

About 1¾ mile further on is another pit in which the strata are regularly exposed and show beds lower down in the series than any yet seen. The following is the section.

Section in Pit No. 4.

Lithology.	Observations.
1. Clay, 2 ft. 6 in.	
2. Stone band, 3 in	*Ostrea irregularis.*
3. Clay with a narrow stone band at places, 2 ft. 6 in.	
4. Stone, 4 in.	*Myacites musculoides* (var. α). *Ostrea irregularis.*
5. Clay, 9 in.	
6. Double soft sandstone band, 4 in.	
7. Clay, 1 ft.	
8. Double stone band, 5 in	Fossils as in 12.
9. Clay, 15 in.	

Section in Pit No. 4 (continued).

Lithology.	Observations.
10. Narrow stone, 2 in.	Fossils as in 12.
11. Clay with sometimes a band of white stone, 2 ft. 3 in.	
12. Sandy stone weathering white, 4 or 5 in.	*Modiola minima.* *Myacites musculoides* (var. β).
13. Blue clay with a spring of water at the top, which colours the section red, 6 ft.	
14. Stone, 4 in.	Fossils as in 12.
15. Clay like 13, 10 ft. to base of the section.	

It is not difficult to correlate these beds with those of pit No. 3. The bed No. 4 is obviously equivalent to the irregular stone layer in No. 30 of pit No. 3, No. 2 to the oyster-bed No. 25, No. 8 to No. 33, and No. 12 to 38; so that we get two lower beds here. Even yet, however, we reach no bone-bed nor any signs of the Keuper marls. The beds of stone in this quarry are very finely laminated and weather white, altogether recalling the White-Lias bands of the south of England. As, however, several beds of clay (the "*contorta*" shales) and stone there intervene above the bone-bed, it is probable that the true horizon of the latter is not reached here, *Avicula contorta* not having been met with even in the lowest clays. Mr. Norwood, in his paper, states that here the Lias is seen gradually changing into the Keuper; but it certainly does not in this quarry, which contains the lowest beds discovered. Can he have mistaken the red weathering of the two lower clay-beds for the red Keuper marls?

No fossils have been found in this quarry beyond those mentioned in the section; and Foraminifera are entirely wanting.

The only place in this neighbourhood where there is any likelihood of seeing lower beds leading down into the Keuper, must be somewhere between Market Weighton and Pocklington, some six or seven miles from Cliff.

About 3 furlongs further on we come to another pit, No. 5, which is not now worked, and consequently the section is not well exposed. In this the white limestone is seen at the base, and oyster-bands occur about 10 feet above it; it has probably therefore been excavated in the same beds as pit No. 4.

The last pit in the series, or pit No. 6, is situated less than a quarter of a mile from No. 5, just at the cross road leading to Hotham. We have there the following section.

Section in Pit No. 6.

Lithology.	Observations.
Surface-soil	Good thickness.
1. Soft calcareous sands, 8 in.	
2. Sandy clay, 7 in.	2, 3, 4 contain broken fragments of *Ostrea irregularis.*
3. Stone, 7 in.	
4. Clay like 2, 8 in.	2, 3, 4 irregular.

Section in Pit No. 6 (continued).

Lithology.	Observations.
5. Strong blue Limestone, 10 in. ...	Fossiliferous; fossils like those of 30, pit No. 3, and 4 pit No. 4.
6. Clay, 1 in.	
7. Calcareous sands, 2 in.	7–9 contain oysters.
8. Bluer clay, 2 ft. 4 in.	
9. Irregular Limestone, 2 in.	
10. Clay, 2 ft. 4 in.	
11. Strong even-bedded Limestone 6 in.	White.
12. Clay, 1 ft.	
13. Three or four softish sandstones, 5 in.	
14. Rather bluer clay, 3 ft.	
15. Narrow white Limestone-band, very regular but septarian, 3 in.	
16. Clay to base, 2 ft.	

I have not been able to secure many fossils from this pit; but there appears little difficulty in correlating its beds to those of pit No. 4. Bed No. 5 in this pit corresponds to No. 4 in that; all above 5 in this corresponds to No. 3 in that; Nos. 6, 7, 8 here to No. 5; No. 9 to No. 6; No. 10 to 7; No. 11 to 8; No. 12 to 9; No. 13 to 10; No. 14 to 11; No. 15 to 12; No. 16 to part of 13, leaving about 13 feet more to be seen in pit No. 4 than in No. 6.

From the fragments of the oyster-bands scattered in this pit I have obtained the following fossils:—

Ichthyosaurus (phalange).
Cerithium, sp.
Myacites musculoides (*Schl.*).
Ostrea irregularis (*Mstr.*).
Ostrea arcuata (*Lam.*)?
Avicula fallax (*Pflücker*).
Montlivaltia Haimei (*Chap. & Dew.*).

These, then, are the Infraliassic sections exposed in the neighbourhood of Cliff; and taking them all together, they give us the beds from the middle of the zone of *Ammonites angulatus* nearly to the horizon where *Avicula contorta* should be found.

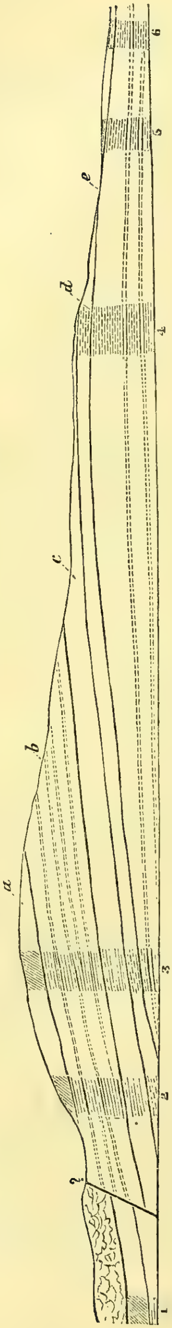
The Middle Lias beds are found half a mile to the east, at Hotham; and it is therefore probable that sections opened in this interval would reveal the higher beds of the Lower Lias. The beds below this series we cannot perhaps hope to find, from the thickness of the alluvial sands which intervene between this and the nearest Keuper beds at Harswell.

With regard to the lie of these beds, there appears to be a slight anticlinal near pit No. 4, in which the lowest beds are seen, and where they seem to have been subjected to some disturbance, being twisted and thrown up in one part into a nearly vertical position.

To the north of this spot the beds dip at a small angle to the N.E., and to the south of it slightly to the S.E. Taking all together we have the general section as represented below (fig. 1).

With regard to the palæontology, it appears that the greater number of fossils can be named from those of the same horizons

Fig. 1.—*Diagram Section of Infraliassic Beds near Cliff, Yorkshire.*



The numbers 1, 2, 3, 4, 5, 6 indicate the pits referred to.

a. Zone of *Am. angulatus.*
b. Am. Johnstoni only. } Zone of *Am. planorbis.*
c. Am. planorbis.

d. Oyster-bands.
e. Clays with white limestones. } White Lias.

elsewhere, although in their distribution there is something peculiar. The definite separation into zones is rather difficult. The upper limestones, in which alone *Am. angulatus* is found, contain a varied fauna, with which there is nothing to compare in the beds below. It is certain, however, that only the lower part of this zone is here exposed. *Am. Johnstoni*, however, ranges through these and the limestones lower down, and is here the most characteristic Ammonite. The true *Am. planorbis* has as yet been found only in one bed; but this is not separated from the others by any other features. The change to the oyster-bands is very marked in pit No. 3, accompanied as it is by a cessation of microscopic fossils; and the same may be said of the change into the white limestone beds below.

On comparing the "*angulatus*" fauna with that of Marton, it will now be seen how nearly allied they are—so much so that it is probable that a complete knowledge of both would prove them to be almost perfectly identical. As at present known, however, they present some decided differences. Of the 44 species recorded as certain from Marton, 23 are also found at Cliff; and it appears possible that an actual comparison of specimens would increase this proportion. Fifty-two species are here recorded as certain from the same horizon, excluding vertebrates and microscopic fossils; of these 15 belong to genera unrepresented at Marton. The difference consists chiefly in the more numerous gastropods and fewer bivalves found at the latter place; for whilst there the proportion is 8 gastropods to 22 bivalves, at Cliff it is 7 to 38, 3 gastropods only being common to both; these, however, and the other common species being those which are most characteristic of the horizon. It appears, however, highly probable that the Marton fossils are from a slightly higher part of the zone of *Am. angulatus.*

The beds at Redcar, when compared with those already described, are very insignificant. On the shore at that place are seen narrow ledges striking seawards, consisting of Lias shale hardened at the top; some few of the most easterly of these contain *Am. angulatus* and other associated fossils. The beds above these contain *Am. Bucklandi*; and no lower beds are anywhere visible, these being only brought up by an anticlinal elevation, and the next beds visible in the same direction being again higher in the series. As, however, all these form part of what I have called the typical Yorkshire basin, their character and contents are best studied in conjunction with the other Liassic beds of that series, and are therefore here passed over.

At Eston, not a mile from the Middle-Lias iron-mines, I saw, in the refuse heaps of a gypsum-shaft, several impressions of Rhætic and Infraliassic fossils, from which we may conclude that the series is complete in this neighbourhood.

References and Notes on the Fossils.

Plesiosaurus. Tooth not unlike that described by Owen as that of *P. rostratus.* Lias Reptiles, pl. 9. I. 4.*

Ichthyosaurus. Vertebra, $1\frac{1}{4}$ inch diameter, probably from III. 18; also a phalange $\frac{5}{8}$ in. by $\frac{3}{8}$ in. in the oyster-bands.

Acrodus minimus (Ag.), Poiss. Foss. vol. iii. pl. 22. figs. 6–12. I. 4.

Dapedius. Tooth. III. 14.

Hybodus (cf.) *minor* (Ag.), Poiss. Foss. vol. iii. pl. 23. fig. 23. III. 16.

Ammonites angulatus (Schl.), Petref. p. 70; Qu. Jura, pl. 3. fig. 1. The form of this, from Cliff, differs much in the narrowness and number of the whorls from that from Redcar. It is rare full-grown at Cliff; but small young specimens are commoner. I. 2, 4.

Am. Johnstoni (Sow.), M. C. pl. 449. fig. 1. There are two varieties of this, not worth separating into species:—1, the ordinary form, with 28 ribs per whorl; and, 2, one with 36 finer ribs. Common in all the upper beds.

Am. planorbis (Sow.), M. C. pl. 448. fig. 1. III. 18 only.

Nautilus striatus (Sow.), M. C. pl. 182. I. 2, 4; II. 1; III. 1, 23.

Trochotoma striatum (Hörn.), Stoliczka, Gast. & Aceph. Hallst. Sch. pl. 5. fig. 2. I. 4; II. 1. There are some smaller shells (those in pit I.) which I think are the young of this. This has some resemblance to *Pleurotomaria trocheata* (Terq.), but is less depressed, and the aperture is more rounded. The genus may be doubtful.

* I. 4. indicates that the fossil is found in pit no. 1, bed 4.

Pleurotomaria nucleus (Terq.), Pal. Hett. pl. 5. fig. 5. One showing the small umbilicus. I. 4.

Phasianella Morencyana (Piette), Terq. & Piette, Lias de l'Est de France, pl. 4. figs. 9–11. ?=*P. nana* (Terq.). I. 2, 4. Common.

Littorina (*Tectaria*) *elegans* (Gldf.), pl. 193. fig. 10. Common in pit I. It is better described and figured by Rolle (Sitz. Ak. Wiss. Wien, Bd. xlii. No. 23) as *Littorina Schimperi*; but a little change in Goldfuss's description would make it include both. He says, "it has four ribs, the upper one knobbed." For this we must substitute four or more ribs, the second and third from below being the strongest—and above these being one or more small ribs, which are the most raised into knobs by the cross ribs. ?=*Amberleya alpina* (Moore).

Melania unicingulata (Terq.), *l. c.* pl. 3. fig. 10 (?). A worn specimen. I.

Turritella Dunkeri (Terq.), *l. c.* pl. 3. fig. 5. I.

Cerithium semele (D'Orb.), Martin, pl. 2. figs. 8–10. II. 8.

Cerithium transversum (n. sp.). This differs from *C. etalense* (Piette), to which I at first referred it, only in having no longitudinal striæ, and having a minute umbilicus, by which two characters, besides its fewer ribs, it is also distinguished from *Chemnitzia Berthaudi* (Dum.). II.

Cerithium, sp. A cast only. VI.

Saxicava arenicola (Terq.), pl. 7. fig. 7. I.

Pleuromya galathea (Ag.), Mon. des Myes. pl. 28. figs. 1–3. I.

Pleuromya striatula (Ag.), *l. c.* pl. 28. figs. 10–12. I.? Compressed specimens.

Arcomya elongata (Röm. sp.), Ool. pl. 8. fig. 1. I. A cast.

Pholadomya glabra (Ag.), *l. c.* pl. 3. fig. 12. I.

Pholadomya Fraasi (Opp.), Juraformation, p. 95=*P. prima* (Qu.), Jura, pl. 5. fig. 2. I.

Myacites musculoides (Schl.), dwarfed form. See Phillips, Geol. of Oxford, pl. 7. fig. 36. III. 30, and IV. 6. The characteristic shell of the White Lias beds here. This appears to correspond to the shell so named by the Geol. Survey; but it seems to me at least doubtful if all can be referred to Schlotheim's species. There may possibly be two species here: the ribs on one (α) are very regular, but become obsolete after a light ridge which runs from the umbo; the other (β) is more irregular.

Cardinia Listeri (Sow.), M. C. pl. 154. figs. 1, 3, 4. I., II., III. 1.

Cardinia ovalis (Stutchb.), An. N. H. 1842, vol. viii. pl. 10. figs. 17–19. I. Common.

Cardinia crassiuscula (Sow.), M. C. pl. 185. II.

Cardinia unioides (Ag.), *l. c.* pl. 12″. figs. 7–9. I., II.

Cardinia lanceolata (Stutchb.), *l. c.* page 484. I. Rather a doubtful determination, perhaps only an elongated variety of *C. ovalis.*

Cardinia Deshayesi (Terq.), *l. c.* pl. 8. fig. 6. I. 4?. I have long thought the specimen now referred to this distinct, and called it *C. inflata*, it being more inflated and more angular posteriorly.

Cardinia Desoudini (Terq.), *l. c.* pl. 9. fig. 1. I.

Astarte Guenxii (D'Orb.)? Prod. vol. i. p. 216. [=*consobrina*, (Chap. & Dew)]. I. The specimens from Cliff do not agree very well with others referred to this species, being smaller, shorter, and with the ribs confined to the umbo; but I am not prepared to separate them.

Astarte cingulata (Terq.), *l. c.* pl. 9. fig. 6. I.

Cardita Heberti (Terq.), *l. c.* pl. 9. fig. 10. I.

Unicardium cardioides (Ph. sp.), Geol. of Yorks. pl. 14. fig. 12. I., II.

Lucina ovulum (T. & P.), Lias de l'Est de France, pl. 8. fig. 14. I. A young specimen connected by invisible gradations with the adult form in specimens from the zone of *A. Bucklandi*.

Protocardia Philippiana (Dkr. sp.), *l. c.* pl. 17. fig. 6. In almost all the beds in the section at Cliff. I regard this as identical with *Cardium rhæticum* (Mer.), and use the earlier name.

Cardium profundum, n. sp. A minute species, rather oblique and deep, and ornamented with numerous (20–24) ribs. Length rather less than the breadth. Most nearly allied to *Cardium Stoppanii* (Renev.); but the ribs are more numerous, and the shell is shorter. I.

Cucullæa hettangiensis (Terq.), *l. c.* pl. 10. fig. 3. I. There are some smaller shells which seem to be the young of this. These specimens have both the posterior ridge and the sulcus running from the umbo, which latter becomes obsolete with age. I.

Cucullæa navicula (Terq. & Piette), *l. c.* pl. 11. figs. 16, 17. I. These differ from the type (which is apparently an old individual) in being narrower and having the hinge-line straighter, but agree in other respects. They cannot be separated.

Leda texturata (Terq. & Piette), *l. c.* pl. 11. figs. 5–7. I.

Modiola minima (Sow.), M. C. pl. 210. figs. 5–7. In all beds. My shells agree better with some others described by foreign authors; but the species is common and characteristic, and is therefore probably the same. See Phil. Geol. of Oxf. pl. 7. fig. 37.

Modiola psilonoti (Qu.), Jura, pl. 4. fig. 13. I.

Myoconcha psilonoti (Quenstedt), Jura, pl. 4. fig. 15. I. In naming this, as well as many others, I must thankfully acknowledge the valuable corrections supplied by R. Tate, Esq., F.G.S.

Mytilus lamellosus (Terq.), *l. c.* pl. 10. fig. 5. I.

Pinna semistriata (Terq.), *l. c.* pl. 11. fig. 1. I.

Perna infraliasica (Qu.), Jura, pl. 4. fig. 19. I.

Avicula longiaxis (Buckman), Geol. of Cheltenham, pl. 10. fig. 2. I. The long hinge is gone in this specimen; but the general form agrees so well, and it appears probable that the corresponding part *was* produced, that I have no doubt of the identification. ?=*A. Pattersoni* (Tate).

Avicula, sp.? (finely costated). III. 10. Lost.

Avicula fallax (Pflücker y Rico), 1865, Rhat. p. 15 (see Braun's Untere Jura, p. 36), =*Monotis decussata* (auct. Angl.). II., III.

Lima gigantea (Sow.), M. C. pl. 77. Common in all the beds. There are numerous smaller specimens, all of which attain the same size, and are more oblique. They may be distinct.

Lima punctata (Sow.), M. C. pl. 113. fig. 12. I.

Lima succincta (Schl.), Taschenb. 1813, p. 72, = *Hermanni* (Voltz.), Goldf. pl. 100. fig. 5. I.

Lima pectinoides (Sow.), M. C. pl. 114. fig. 4, = *L. acuticosta*, in Tate, Geol. Journ. 1867, p. 312. Common in pit I. There are some specimens more oblique, with curved hinge-line, and having no sign of any intermediate ribs at all. They are of small size, and *may be* the young of the above, though there are others as small not showing these characters. If they prove distinct, they should be called *L. pura*.

Lima fallax? (Chap. & Dew), Terr. Sec. de Lux. pl. 27. fig. 4. I., II. Small specimens, mostly casts.

Pecten punctatissimus (Qu.), Der Jura, pl. 9. fig. 14. I. Common.

Pecten textilis (Mstr.), Gldf. pl. 89. fig. 3. I.

Pecten æqualis (Qu.), *l. c.* pl. 9. fig. 13. I. 5.

Pecten pollux (D'Orb.), Prodrome, p. 220. Oyster-bands.

Ostrea irregularis (Mstr.), Gldf. pl. 79. fig. 5, = *O. sublamellosa* (Dkr.), and *O. liassica* (Strickl.). There are specimens exactly corresponding to all these, which, however, I regard as one species. They are common in all the beds, and are the oysters which form the "oyster-bands." Two varieties may be marked:—var. *ungula* (Mstr.); and var. *concava*, like var. *ungula*, but the attached valve very concave, and only attached at the umbo.

Ostrea arcuata (Lamk.), An. S. Vert. p. 398, = *Gryphæa incurva* (Sow.), M. C. pl. 112. figs. 1, 2. VI. Not found *in situ*, *possibly* from the surface.

Waldheimia perforata (Piette), Bull. Soc. Géol. de France, t. 13. pl. 10. fig. 1, = *Terebratula psilonoti* (Qu.). I., II.

Serpula capitata (Ph.), Geol. of Yorks. pl. 14. fig. 16. I.

Serpula plicatilis (Mstr.), Goldf. pl. 68. fig. 2. I.

Serpula socialis (Goldf.), pl. 69. fig. 12, = *Galeolaria filiformis* (Terq. & Piette). I., II.

Cidaris Edwardsii (Wr.), Brit. Foss. Ech. pl. 1. fig. 1. Represented by a plate and numerous spines. I.

Hemipedina Tomesii (Wr.), *l. c.* p. 457. I. 5. A test and numerous spines, also teeth probably belonging to this. Spines of another species; longitudinal ribs toothed. I.

Pentacrinus psilonoti (Qu.), *l. c.* pl. 5. fig. 7. Common in all the upper beds.

Septastræa excavata (From.), Martin, *l. c.* pl. 8. figs. 1–5. I. A magnificent specimen, 10 in. by 7 in. by 4 in.

Montlivaltia Haimei (Chap. & Dew.), *l. c.* pl. 38. fig. 5. II., VI.

FORAMINIFERA.

It is unadvisable here to attempt a full description of these, as they are exceedingly numerous, and, when fully studied, likely to add much to the knowledge of the microscopic fauna of the Lias; the chief features of the fauna, however, may be noticed.

Nodosaria.—Of this there are smooth varieties, elongated like *N. radicula* (L.), and shortened like *N. glans* (D'Orb.); and also striated varieties, thick like *N. raphanistrum* (L.), and narrow like *N. lineolata* (Rss.).

Dentalina.—This is in great abundance and variety. Of smooth kinds, some are oblique, as *D. communis* (D'Orb.) and *D. obliqua* (D'Orb.); some have the cells perpendicular to the axis, as *D. pauperata* (D'Orb.), or elongated, as *D. monile* (Rss.); and there are others differing from all the well-known forms. There are also some ribbed varieties, as *D. obliquestriata* (Rss.).

Lingulina.—Some few may be referred to *L. tenera* (Born.).

Frondicularia.—These are the characteristic Foraminifera of the beds, occurring in great abundance, but not in very numerous varieties; they may be referred to *F. pulchra* (Terq.), and other species of that author.

Vaginulina is present in its usual form of *V. legumen* (L.).

Planularia.—The identity of these with the forms previously described by Brady from the Lias of S.W. England is very marked, *P. Bronnii* (Röm.), *P. cornucopiæ* (Brady), and *P. pauperata* (P. & J.) being common.

Marginulina.—These are present in the form of *M. raphanus* (L.), ribbed, and *M. lituus* (D'Orb.), smooth, besides many other less-known forms.

Flabellina rugosa (D'Orb.) is certainly present, though rare.

Cristellaria.—These are abundant and present nothing novel, all being referable to *C. crepidula* (F. & M.), *C. cassis* (F. & M.), *C. rotulata* (Lam.), and other well-known varieties.

Lagena.—These are among the most interesting of the collection. There are two distinct sets of varieties—one elongated and narrow, like those called "Oolina" by foreign authors, and the other small and globular, variously ornamented, as *L. sulcata* (W. & J.).

Polymorphina.—These are in great variety, and cannot be named with accuracy. Some compare well with *P. lactea* (W. & J.) and *P. gutta* (D'Orb.), and many with *P. bilocularis* (Terq.) and others of that author. Some may eventually turn out to be *Buliminæ.*

Textilaria.—Two well-marked specimens are all that have been found of these; they differ from all well-known forms.

Triloculina.—One doubtful specimen appears to represent this genus.

Cornuspira.—Numerous specimens of this, mostly casts, can scarcely be distinguished from *C. infima* (Strickl.).

Webbina.—Some specimens of this, with irregular chambers, occur attached to fragments of shells. They may probably be identified with *W. irregularis* (D'Orb.).

Lituola.—There are several specimens in casts, which have the appearance of Rotalines, but are supposed to belong to anomalous forms of this genus. The absence of the original shell renders the decision perhaps impossible.

Note.—Among the microscopic fossils are two which require notice from their liability to be taken for Foraminifera :—1. Some hook-shaped spicules ending generally in a complete circle at one end. They are described by Terquem as Foraminifera, under the name of *Uncinulina polymorpha*, in his 'Mém. sur les Foram. du Lias,' but have since been recognized by him as spicules of *Astrophyton* (*Saccocoma*), Terq. & Jourdy, Et. Bathon. de la Moselle, pl. 15. fig. 12–14. 2. Some joints of a Crinoid (?), thin and flat, and perforated with numerous large openings disposed in a subcruciform manner, resembling the cut section of a *Nubecularia*.

APPENDIX. *On some* BIVALVE ENTOMOSTRACA *from the* LIAS (" INFRA-LIAS ") *of* YORKSHIRE. By Prof. T. RUPERT JONES, F.G.S.

1. BAIRDIA (?) ELLIPSOIDEA, G. S. Brady, MS.

Carapace ovato-trigonal; somewhat compressed; highest (broadest) in the anterior third. Valves smooth, thick; right valve the largest, overlapping the other on the dorsal and ventral borders, and marked with a furrow within each of those edges for the reception of the fellow valve. Length $\frac{1}{48}$ inch. Four specimens.

This somewhat resembles *Bairdia ovata*, Bosquet, sp. ('Mém. Commission descr. Carte Géol. Néerlande,' vol. ii. p. 73, pl. 5. fig. 6), and probably belongs rather to *Pontocypris* than to *Bairdia*, both of which are marine members of the family *Cypridæ*. See G. S. Brady's "Monograph of the Recent British Ostracoda," Linn. Trans. vol. xxvi. p. 360, &c.

2. CYTHERE MOOREI, G. S. Brady, MS.

Carapace tumid; egg-shaped, with terminal lips and flattened ventral surface; somewhat like a peach-stone in shape and ornament. Surface of the valves reticulate; the meshes rather coarse on the middle, but having a tendency to become longitudinal and parallel on the sides and towards the extremities.

Length $\frac{1}{32}$ inch. Three specimens.

In general form this approaches *C. striatopunctata* (Römer) and *C. concentrica* (Reuss); but the reticulation differs. It takes its name after Mr. Charles Moore, F.G.S., one of the most enthusiastic of geologists, and a successful labourer among Lias fossils.

3. CYTHERE BLAKEI, sp. nov.

Carapace oblong, subcylindrical, with marginal lips at the ends, obliquely rounded in front, contracted and rounded behind, somewhat compressed dorsally at the median third. Surface rough, with faint irregular reticulation, and bearing traces of ventral striæ.

Length $\frac{1}{48}$ inch. Three specimens.

Cythere clathrata, Reuss, and its allies have this form of carapace; but the details are distinct. The name of its discoverer, the Rev. J. F. Blake, F.G.S., distinguishes this species.

4. CYTHERE TERQUEMIANA, sp. nov.

Carapace narrow-oblong, incurved on the back by the projection of the anterior hinge, and pinched in between that hinge and the muscle-spot; rounded at the ends, with broad delicate margins, that of the front divided into about eight neat fossets. Surface sculptured with a coarse, irregularly hexagonal network, about eight meshes to the transverse width of the valve.

Length $\frac{1}{50}$ inch. Three specimens.

This form reminds us of the Tertiary *Cythere canaliculata* (Reuss) and its varieties; but its compression is stronger and more central, and its reticulation has far less tendency to run into ridges by the hypertrophy of the meshes.

This species is dedicated to M. O. Terquem, the veteran explorer of the Lias of Metz and its neighbourhood.

DISCUSSION.

Prof. DUNCAN remarked that English geologists had been backward in receiving the term Infralias, which he had suggested with respect to the Sutton Down beds some years ago, and the propriety of which was shown by the term having been applied to the same beds by French geologists at a still earlier period. As to the White Lias, he regarded it as a mere local deposit, not to be found out of England. He traced the existence of the Infralias from Luxembourg through France into South Wales, where Corals were abundant. In Yorkshire, though one fine Coral had been found, the Ammonites seemed to point to a difference in condition.

Mr. HUGHES remarked that the lithological character of the beds, as described by the author, did not agree with that of the Infralias in the S.W. of England or the N. of Italy, and that the palæontological evidence which had been laid before the Society did not confirm the view that they were Infralias. Also, by reference to the author's section, Mr. Hughes pointed out that below what he described as Infralias he drew other beds which were not Trias, the author having explained that some beds which had been called Trias were only stained beds of Liassic age.

The Rev. J. F. BLAKE, in reply, acknowledged the differencce between the Yorkshire section and those of the neighbourhood of Bath, but insisted on the similarity of the fossils.

FEBRUARY 7, 1872.

W. G. Thorpe, Esq., of Gloucester House, Larkhall Rise, S.W., and Barton's House, Ipplepen, Newton Abbot, and James Plaat, Esq., of 40 West Terrace, West Street, Leicester, were elected Fellows of the Society.

The following communications were read:—

1. Further Notes *on the* Geology *of the neighbourhood of* Malaga. By M. D. M. d'Orueta. Communicated by the President.

[Abstract*.]

In this paper, which is a continuation of a former note laid before the Society (see Q. J. G. S. xxvii. p. 109) the author commenced by stating that his former opinion as to the Jurassic age of the rocks of Antequera is fully borne out by later researches upon their fossils. They apparently belong to the Portlandian series. The author made considerable additions to his description of the Torcal, near the foot of which he has found a sandstone containing abundance of *Gryphæa virgula* and *Ostrea deltoidea*. This he regards as equivalent to the Kimmeridge Clay. In the Torcal he has also found a soft, white, calcareous deposit, overlying the limestones of supposed Portlandian age, and containing a fossil which he identifies with the Tithonian *Terebratula diphya*. The author discussed the peculiar forms assumed by the rocks of the Torcal under denudation, which he supposed to be due originally to the upheaval caused by the rising of a great mass of greenstone, portions of which are visible at the surface on both sides of the range.

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2. *On the* River-courses *of* England *and* Wales. By Prof. Andrew C. Ramsay, LL.D., F.R.S., V.P.G.S.

In the following paper I propose to show the origin of many of the principal rivers of England and Wales—that is to say, what are the special geological causes the operation of which led them to flow in the general directions they now take. I am not aware that any attempt has heretofore been made to do this on a large scale, though I have already done something on the subject with regard to the rivers of the Weald, in which line of argument I was afterwards followed by Mr. Foster and Mr. Topley.

I shall begin the subject by a rapid summary of certain physical changes that affected the English Secondary and Eocene strata, long before the Severn (leaving the mountains of Wales) took its present southern and south-western course along the eastern side of the palæozoic rocks that border that old land.

About the close of the Oolitic epoch the strata of these formations were raised above the sea, and remained a long time out of water; and during that period those atmospheric influences that produced the sediments of the great Purbeck and Wealden delta were slowly wearing away and lowering the land, and reducing it to the state of a broad undulating plain. At this time the Oolitic strata still abutted on the mountain country now forming Wales and parts of the adjacent counties. They also completely covered the Mendip Hills, and

* The publication of this paper is deferred.

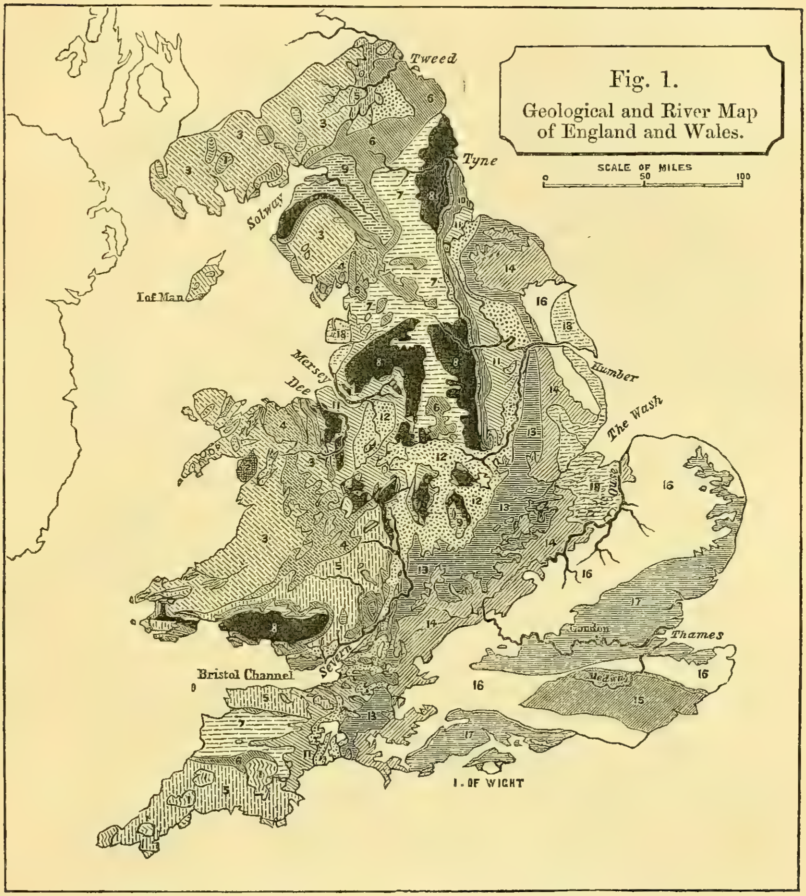


Fig. 1.
Geological and River Map of England and Wales.

- 18. Alluvium, Drift, &c.
- 17. Crag and Eocene.
- 16. Cretaceous.
- 15. Wealden.
- 14. Oolitic strata.
- 13. Liassic strata.
- 12. Keuper Marl &c. } Trias.
- 11. Bunter Sandstone. } Trias.
- 10. Magnesian Limestone, Permian.
- 9. Rothliegende, Permian.
- 8. Coal-measures. } Carboniferous.
- 7. Millstone-grit. } Carboniferous.
- 6. Mountain-limestone. } Carboniferous.
- 5. Devonian.
- 4. Upper } Silurian.
- 3. Lower } Silurian.
- 2. Cambrian.
- 1. Granite &c.

passed westwards as far as the hilly ground of Devonshire, running out between Wales and Devonshire through what is now the Bristol Channel. The whole of the middle of England was likewise covered by the same deposits, viz. the plains of Shropshire, Cheshire, Lancashire, and the adjoining areas; so that the Lias and Oolites passed out to what is now the Irish Sea, over and beyond the present estuaries of the Dee and the Mersey, between North Wales and the hilly ground of Lancashire, formed of previously disturbed Carboniferous rocks. In brief, most of the present mountainous and hilly lands of the mainland of Britain were mountainous and hilly then, and even higher than now, considering how much they must since have suffered by denudation.

At this period, south of the Derbyshire hills and through Shropshire and Cheshire, the Lower Secondary rocks lay somewhat flatly; while in the more southern and eastern areas they were tilted up to the west, so as to give them a low eastern dip. The general arrangement of the strata in the south would then be somewhat as shown in fig. 2 (p. 151).

The submersion of this low-lying area brought the deposition of the Wealden strata to a close, and the Cretaceous formations were deposited above the Wealden and Oolitic strata, so that a great unconformable overlap of Cretaceous strata took place across the successive outcrops of the Oolitic and older Secondary formations, as shown in fig. 3 (p. 151).

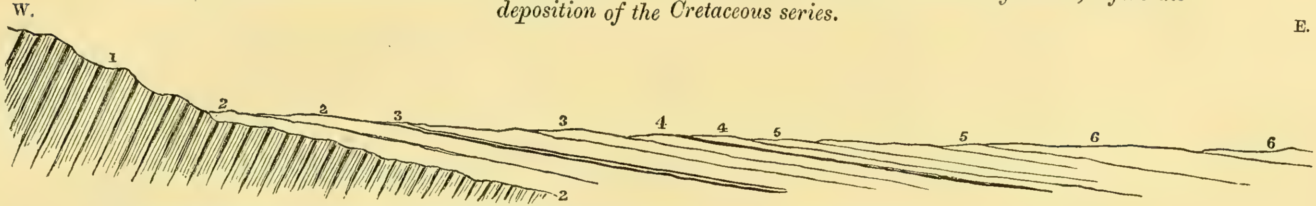
The same kind of overlapping of the Cretaceous on the Oolitic formations took place at the same time in the country north and south of the present estuary of the Humber, the proof of which is well seen in the unconformity of the Cretaceous rocks on the Oolites and Lias of Lincolnshire and Yorkshire.

At this time the mountains of Wales and other hilly regions formed of Palæozoic rocks must have been lower than they were during the Oolitic epochs, partly by the effect of long-continued waste, due to atmospheric causes, but probably even more because of gradual and greatly increased submergence during the time that the Chalk was being deposited. I omit any detailed mention of the phenomena connected with the deposition of the freshwater and marine Eocene strata, because at present this subject does not seem essential to my argument.

The Miocene period of old Europe was essentially a continental one. Important disturbances of strata brought this epoch to a close, at all events physically, in what is now the centre of Europe; and the formations formed in the great freshwater lakes that lay at the bases of the older Alps were, after consolidation, heaved up to form new mountains along the flanks of the ancient range; and all the length of the Jura, and far beyond to the north-west, was elevated by disturbances of the Jurassic, Cretaceous, and Miocene strata. The broad valley of the lowlands of Switzerland began then to be established, subsequently to be overspread by the large glaciers that deepened the valleys and scooped out the lakes.

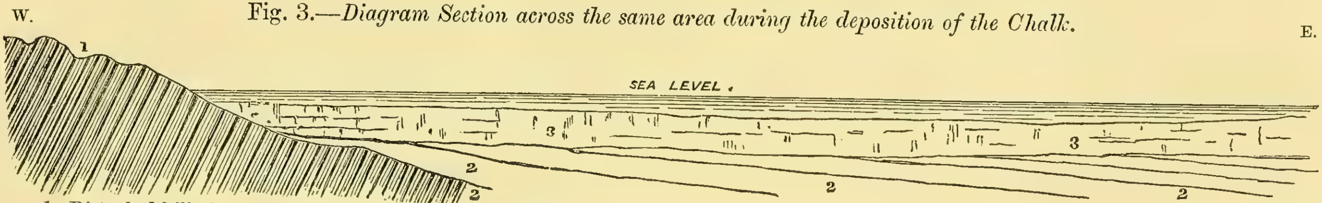
One marked effect of this extremely important elevation, after Miocene times, of so much of the centre of Europe was, that the flat

Fig. 2.—*Diagram Section from the Mountains of S. Wales across the Lower Secondary strata, before the deposition of the Cretaceous series.*



1. Disturbed and hilly Silurian, Old Red, and Carboniferous strata.
2. New Red series.
3. Rhætic and Liassic series.
4, 5, 6. Lower, Middle, and Upper Oolites.

Fig. 3.—*Diagram Section across the same area during the deposition of the Chalk.*



1. Disturbed hilly land, as in Fig. 2.
2. New Red, Liassic and Oolitic strata.
3. Cretaceous strata lying unconformably on and overlapping the denuded edges of No. 2, and abutting on the half-submerged mountains of Wales.

or nearly flat-lying Secondary formations that now form great part of France and England (then united), were so far affected by this renewed upheaval of the Alps and Jura, that they were all tilted at low angles to the north-west. That circumstance gave the initial north-westerly direction to the flow of so many of the existing rivers of France, and led them to excavate the valleys in which they run, including the upper tributaries of the Loire and Seine, the Seine itself, the Marne, the Oise, and many more of smaller size; and my surmise is, that this same westerly and north-westerly tilting of the chalk of England formed a gentle slope towards the mountains of Wales, and the rivers of the middle and south of England at that time flowed westerly. This first induced the Severn to take a southern course, between the hilly land of Wales and Herefordshire and the long slope of Chalk rising to the east; and, aided by the tributary streams of Herefordshire, it cut a channel towards what afterwards became the Bristol Channel, and established the beginning of the escarpment of the chalk (*e*, fig. 4, p. 154), which has since gradually receded, chiefly by atmospheric waste, so far to the east. If this be so, then the origin of the valley of the Severn is of immediate post-Miocene date, and it is one of the oldest in England *.

The Avon, which is a tributary of the Severn, and joins it at Tewkesbury, is, at all events, partly of later date. It rises at the base of the escarpment of the Oolitic rocks east of Rugby, and gradually established its channel in the low grounds formed of Lower Lias and New Red Marl, as that escarpment retired eastward by virtue of that law of waste, that all inland escarpments retire opposite to the steep slope, and in the direction of the slope of the strata.

If the general slope of the surface of the chalk had been easterly instead of westerly at the post-Miocene date alluded to, then the initial course of the Severn would also have been easterly, like that of the Thames and the rivers that flow into the Wash and the Humber.

This at once leads to the question, Why is it that the Thames and other rivers that flow through the Oolites and Chalk run eastward? The answer seems to me to be, that after the original valley of the Severn was cut out by its river a new disturbance of the whole country took place, by which the Cretaceous and other strata were tilted eastward, and not suddenly, but by degrees, an initial slope was given to the Chalk and Eocene strata, east of the comparatively newly formed escarpment of the Chalk indicated by the dark line in fig. 4, marked *e*. The Chalk escarpment, in its beginning, is thus of older date than the Oolitic escarpment, though it would be hard to find this out except on the hypothesis I have stated. The Thames, then, in its beginning, from end to end, flowed easterly over Chalk and Eocene strata, and the river was larger then than now. But by processes of waste identical with those that formed the escarpment of the Wealden, the Chalk escarpment gradually

* Many of the valleys of Wales may be much older.

receded eastward; and as it did this the area of drainage contracted. By and by the outcropping edges of Oolitic strata became exposed, and a second and later escarpment began to be formed; but the escarpment of the Chalk being more easily wasted than that of the Oolite, its recession was more rapid.

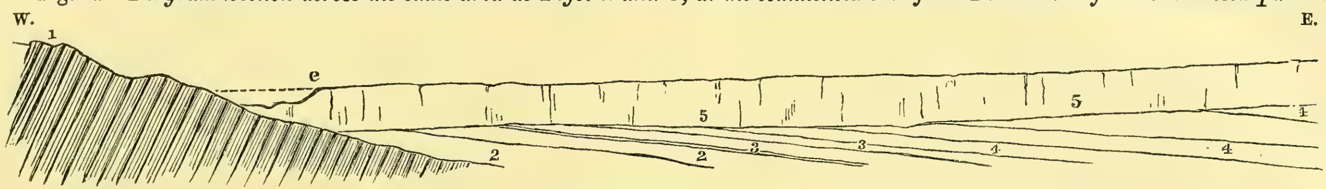
All this time the Thames was cutting a valley for itself in the Chalk; and by and by, when the escarpment had receded to a certain point, its base was lower than the edge of the Oolitic escarpment that then as now overlooked the valley of the Severn; only at that time the valley was narrower. While this point was being reached, the Thames by degrees was joined by the waters that drained part of the surface of the long eastward slope of the Oolitic strata, the western escarpment of which was still receding; and thus was brought about what at first sight seems the unnatural breaking of the river through the high escarpment of the Chalk between Wallingford and Reading. This, also, is the reason why the so-called sources of the Thames, the Seven Springs and others, rise so close to the great escarpment of the Inferior Oolite east of Gloucester and Cheltenham. But the sources of the river now are not more stationary than those that preceded them. The escarpments both of Chalk and Oolite are still slowly changing and receding eastward, and as that of the Oolite recedes, the area of drainage will diminish and the Thames decrease in volume. This is a geological fact, however distant it may appear to persons unaccustomed to deal with geological time.

The same kind of argument is applicable to the Ouse, the Nen, the Welland, the Glen, and the Witham, rivers flowing into the Wash, all of which rise either on or close to the escarpment of the Oolites, between the country near Buckingham and that east of Grantham, on rocks which were once covered by the Chalk.

With minor differences, the same general theory equally applies to all the rivers that run into the Humber. I believe the early course of the Trent was established at a time when, to say the least, the Lias and Oolites overspread all the undulating plains of New Red Marl and Sandstone of the centre of England, and passed out to what is now the sea, beyond the estuaries of the Mersey and the Dee. A high-lying anticlinal line threw off those strata, with low dips to the east and west; and, after much denudation, the large outlier of Lias between Market Drayton and Whitchurch, in Shropshire, is one of the western results. Down the eastern slopes the Trent began to run across an inclined plain of Oolitic strata. Through long ages of waste and decay the Lias and Oolites were washed away from all these midland districts, and the long escarpment formed of these strata now lies well to the east, overlooking the broad valley of New Red Marl through which the river flows.

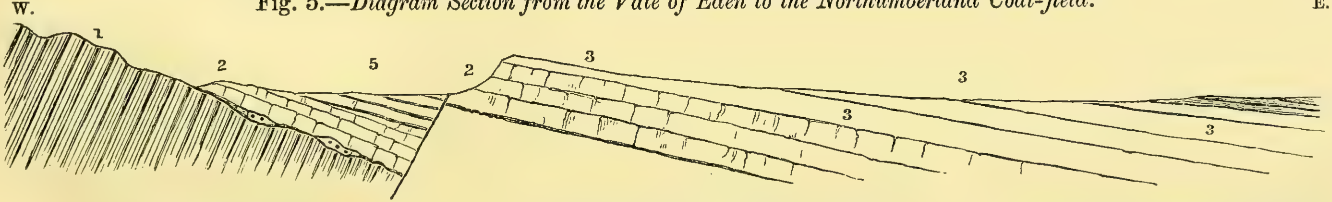
The most important tributary of the Trent is the Derwent, a tributary of which is the Wye of Derbyshire. The geological history of the latter river is very instructive. It runs right across part of the central watershed of England formed by the great boss of the Carboniferous Limestone of Derbyshire. This course, at first sight,

Fig. 4.—*Diagram Section across the same area as Figs. 2 and 3, at the commencement of the Formation of the Chalk escarpment.*



1. Palæozoic rocks.
2. New Red Series.
3. Rhætic and Liassic Series.
4. Oolitic Series.
5. Chalk.

Fig. 5.—*Diagram Section from the Vale of Eden to the Northumberland Coal-field.*



1. Silurian rocks.
2. Carboniferous Limestone.
3. Millstone Grit and Yoredale rocks &c.
4. Coal-measures.
5. Permian Sandstones and Marls.

seems so unnatural, that the late Mr. Hopkins, of Cambridge, stated that it was caused by two fractures in the strata running parallel to the winding course of the river. There are no fractures there of any importance. The true explanation is this. At an older period of the physical history of the country, the valley north and west of Buxton had no existence, and the land there actually stood higher than the tops of the limestone hills to the east. An inclined plain of denudation stretched eastward, giving an initial direction to the drainage of the country. The river began to cut a channel through the limestone rocks; and as it deepened and formed a gorge, the soft carboniferous shales where it rose also got worn away by atmospheric action, and from the north and west streams began to run into the Wye. By the power of running water those valleys all deepened simultaneously and proportionately to the distance from the rise of the river, because the further it flowed the more was its volume increased by the aid of tributary streams and springs. Thus it happened that the Wye seems unnaturally to break across a boss of hills which, however, were once a mere undulating unbroken mass of limestone. But there is no breakage, and nothing violent in the matter. It was a mere case of the wearing action of running water cutting a channel for itself from high to lower levels, till, where Rowsley now stands, it joined the Derwent, which flows in a long north and south valley scooped by itself chiefly in Yoredale shales, between the high terraced scarps of Millstone-grit and the grassy slopes of the Carboniferous Limestone.

When we come to the other rivers that enter the Humber north and west of the Trent the case is more puzzling. The Oolites in that region were extensively denuded before the deposition of the Chalk—so that between Market Weighton and Kirkby-under-dale, in Yorkshire, the Chalk is seen completely to overlap unconformably the Oolitic strata, and to rest directly on the Lower Lias, which is there very thin. The Chalk therefore overspread all these strata to the west, and lay directly on the New Red beds of the vale of York, till, overlapping these, it probably intruded on the Carboniferous strata of the Yorkshire hills further west, while the Oolites of the northern moorlands of Yorkshire also spread westward till they encroached on the Carboniferous slopes. The denuded remains of the latter now rise above the beautiful valleys of Yoredale and Swaledale, the whole, both Carboniferous and Secondary strata, having gentle eastern and south-eastern dips. These dips gave the rivers their initial tendency to flow south-east and east; and thus it was that the Wharfe, the Ouse, and the Swale, cutting their own channels, found their way to what is now the estuary of the Humber, while the escarpments of the Chalk and Oolite were gradually receding eastward to their present temporary positions.

That the Oolitic strata spread northward beyond their present edges is quite certain; but whether or not they extended far enough to cover the whole of the Durham and Northumberland coal-field, I am unable to say. Whether they did so or not does not materially affect the next question to be considered; for if they did spread over part of these Carboniferous strata, they must have thinned away to a feather edge before the Oolitic escarpment began to be formed.

Taken as a whole, from the great escarpment of Carboniferous Limestone that overlooks the vale of Eden on the east, all the Carboniferous strata thence to the German Ocean have a gentle eastern dip—so gentle, indeed, that, on Mallerstang and other high hills overlooking the vale of Eden, outlying patches of the Lower Coal-measures or Gannister beds still remain to tell that once the whole of the Coal-measures spread across the country as far as the edge of the vale of Eden, and even far beyond, in pre-Permian times. These gentle eastern and south-eastern dips, caused by upheaval of the strata on the west and north-west, gave the initial tendency of all the rivers of the region to flow east and south-east; and thus it happens that the Tees, the Wear, the Derwent, the Tyne, the Blyth, the Coquet, and the Alne have found their way to the German Ocean, cutting and deepening their channels as they ran. The sides of these valleys, widened by time and subaerial degradation, now rise high above the rivers in the regions west of the Coal-measures, in a succession of terraces of limestone bands, tier above tier, as it were in great steps, till on the tops of the hills we reach the Millstone-grit itself.

We now turn to the western rivers of England, about which there is far less to be said.

First the Eden. This river flows through the whole length of the beautiful valley of that name, through Permian rocks, for nearly forty miles. At the mouth of the valley, at and near Carlisle, a patch of New Red Marl lies on the Permian Sandstones; and on the Marl rests the Lias. Whether the whole length of the Permian strata of the Vale of Eden was once covered by these rocks, it is impossible to determine; but I believe that it must have been so to some extent, and also that the Lias was probably covered by Oolitic strata. As these were denuded away by time, the Eden began to establish itself, and now runs through rocks in a faulted hollow in the manner shown in fig. 5 (p. 154). What is the precise date of the formation of this great valley and its river-course I am unable to say; but I believe that it may approximately be of the same age as the valleys last described. And so with the other rivers of the west of England, the Lune, the Ribble, the Mersey, and the Weaver—unless, indeed, some of these rivers, including the Dee, had their western courses determined by that western tilting of the strata that I believe originally established the greater part of the channel of the Severn.

I have already said that the rivers of Wales, the sources of the Severn, and all the other rivers that flow through the high Palæozoic rocks are difficult to treat of in a definite manner; so highly disturbed are most of the rocks, and so ancient are those disturbances. The mountains there are, to say the least, pre-Permian, though it does not therefore follow that the present valleys date from that venerable age. The great tableland of South Wales, in

Cardiganshire, Caermarthenshire, part of Pembrokeshire, and in parts of other adjacent counties is, I consider, of older date than the Carboniferous strata; and I also consider that great part of that ancient Silurian tableland was overspread by these strata. On their removal by denudation, that tableland was attacked by all the ordinary powers of waste; and now, a modified descendant of a pre-Carboniferous plateau, it is traversed by unnumbered valleys and streams that run towards every point of the compass, mostly across the strike of the strata, but some, like the Towey of Caermarthenshire, and the Teivi of Cardiganshire, along the lines of strike for long parts of their courses, where comparatively soft slates and Llandeilo flags form the surface, bordered by hills formed of harder rocks. Some of the rivers, like the Wye and the Usk of South Wales, run right through bold escarpments, in the manner of the Thames; and similar cases in North Wales are not wanting. But this part of a very large subject I hope to return to in a future paper, should I find time to prepare it.

Discussion.

Mr. Hughes pointed out that in Wales and the Lake-district, which in this question might be considered as one, there were two plains of marine denudation—the one referred to by Prof. Ramsay averaging a little over 2000 ft., and the other about 3000 ft. above the sea. Such plains get eaten back and cut up into valleys; but their general level does not get much lowered by subaërial denudation. Therefore, in considering the western drainage-area of the ancient Severn, it was important to fix the age of these plains. He did not agree with Prof. Ramsay that the 2000-ft. plain was pre-Carboniferous, as the Carboniferous and Old Red hills of South Wales and, in a more marked way, those of West Yorkshire and the Lake-district were evidently cut down by the same denudation that planed off the top of the Silurian area, and their tops formed part of the same plain. He did not think that this plain could be even pre-Oolitic; for the shingle-beach of the Trias, which might be regarded as the basement-bed of the Jurassic series, was evidently formed round the margin of that old land, whereas had this plain existed there would not have been land sufficiently high to arrest the Jurassic sea during the period of greatest submergence; and a conglomerate implies a shore near. The absence of a coarse shore-deposit at their base, and the character of the Cretaceous deposits, also would lead him to infer that the Chalk-sea probably washed no land so near as Wales; but it was quite possible that the chalk was removed from the Welsh area when the 2000-ft. plain was formed; and in that case we should refer the initial Severn to the time when the deposits of the sea that formed that plain were being eaten back, and not to the time when the Chalk was being removed. He asked where were the valleys when the drainage of the eastern area ran west into the Severn, as there was considerable difficulty in supposing that the main westerly drainage was in reverse direction along the same lines as that of the modern easterly streams. He pointed out that the great W.N.W. disturbances, many, if not all, of which were in part post-Tertiary, must be taken into account in this inquiry: *e. g.* the synclinal of central Devon running into the English Channel near the Isle of Wight—the anticlinal of the British Channel and the Weald, which we know was a barrier in pre-Carboniferous times, from the different character of the Coal-measures of Wales and the Culm-measures of Devon—Mr. Godwin-Austen's ridge bringing up the old rocks under London—the barriers which caused the Lower and Upper Silurian of S. Wales to differ so much from those of N. Wales and the Lake-district, and were the indirect cause of the bosses of Silurian rocks which project through the newer rocks in Central England—the barriers that divided the northern coal-fields—the Craven Faults and the great valley which runs along them,—these and many others have obviously affected recent denudation. A slight tilt to the west would send the drainage again to the west along some of them; and the question involved the consideration of all traces of changes of level.

Prof. Duncan observed that one important point in the paper was the hypothetical dip of the Chalk, on which the existence of the Severn was made to depend; and commented on the denudations which must have taken place during the Glacial and Pliocene periods. He differed from the author in his view of the character of the Oolitic period, which he regarded as one of great oscillation. As to the amount of Palæozoic land-surface in Cretaceous times, he maintained that the purity of the Chalk deposits and their freedom from any terrestrial waste bore evidence of the distance of the land at that time. The depth of the sea in which they were formed was immense; and in the Upper Cretaceous period the oscillations were also great. He disputed the fact of the Miocene period of Europe having been continental in character, especially as regards the upper and middle parts of the deposits, in which Corals abundantly occurred. The elevation of the Alps was, he maintained, of a slow progressive character, which could hardly have affected so great an area as supposed by Prof. Ramsay.

Mr. Evans called attention to the relation of the present flow of many rivers to the last elevation of the land at the close of the Glacial period. The deposits of the Severn valley, he thought, proved its preglacial origin, and consequently supported Prof. Ramsay's argument; but the condition of the land at the close of the Glacial period was also to be fully taken into consideration, as the previously existing channels had in many instances been obliterated during that period. To a great extent Mr. Evans agreed with Prof. Ramsay, but he would wish to see the explanation carried down to a later date.

Mr. Green remarked, in illustration of the retrogression of escarpments, that he had had some opportunity of observing the process while still in progress. In the Carboniferous rocks of the north of England, where the dip of some hard rock was in a certain direction and it was overlain by softer strata, it was constantly the case that a brook ran along the line of junction, undermining the softer beds, bringing them down into the stream, and then removing them. It was thus that escarpments receded.

Prof. MORRIS remarked that at an early period the Alps on the south, and the Cumberland mountains on the north, formed the boundaries of a sort of trough, and that this to some extent must have influenced the flow of the rivers both in Britain and on the Continent. He considered that the series of elevations in pre-Permian times had also much to do with the configuration of some parts of the country, and therefore of its river-basins. The evidence of the Oolitic series was that it was deposited in an area of gradual depression, which was subsequently again elevated; and there was no doubt of the existence of a large amount of land over a great part of Central England during the deposition of some of the later Oolitic beds. Then again came a depression during the period of the White Chalk. With regard to the Severn valley, he recalled the observations of Sir R. Murchison as to its having been an ancient marine channel, connecting the estuary of the Ribble and what is now the Bristol Channel. He cited Prof. Phillips to account for the presence of the Lickey quartz pebbles in the valley of the Thames by the existence of ancient lochs in the Glacial sea.

Mr. WHITAKER remarked on the probable extension of the Chalk as far as the Scilly Islands, which was evinced by the flints found on the surface there and in the Land's-End district. He attributed the fact of so many of the streams breaking through the chalk escarpment on the south and so few on the north in the London basin to the difference of the dip in the two cases.

The PRESIDENT could not give in his adhesion to Prof. Ramsay's opinion. To establish so general a view as that propounded, he thought that a more extensive array of facts with regard to the conditions of the river-valleys should have been adduced. He wished for evidence as to the existence of old river-gravels at a greater elevation above the present river Severn, for instance, than that adduced by the author. The elevation of the Alps he regarded as not sufficient to account for the lines of drainage in Britain. It was to be borne in mind that during the Quaternary period the excavatory force of the rivers was much greater than at the present day. He thought there was still much to be learnt as to the causes which led to the direction and extent of the present river-valleys, the original rudiments of which were probably due to other causes than river-action.

Prof. RAMSAY, in reply, was inclined to restrict himself to the immediate subject of his paper. With regard to the so-called Straits of Malvern, he accepted the view so far as it assumed that an ancient river-valley had, by submergence, been converted into a strait. He had purposely omitted in his paper all consideration of the Glacial period, for the simple reason that the initial direction of the river-valleys had been given in preglacial times. His object was merely to show the causes of the initial direction of the rivers; and he could not be expected, in a paper before the Geological

Society, to take these minor points into serious consideration. The Trias he had always regarded as a great inland salt-lake deposit, which of course involved such terrestrial conditions as those which had been pointed out. He could not agree that some intercalations of marine beds destroyed the generally continental character of the Miocene beds of the northern half of Europe. He repudiated the idea of an immediate connexion between the elevation of the Alps and the flow of the Severn, though such a general tilting of the strata as that of which the last elevation of the Alps was one of the principal results, produced its effects upon a wide area in Western Europe. The volume of the rivers in former times had nothing to do with his subject; but the cutting back through escarpments was, he thought, best explained in the manner he had suggested.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPERS.

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1. *On the* CARBONIFEROUS FLORA *of* BEAR ISLAND (lat. 74° 30′ N.). By Prof. OSWALD HEER, F.M.G.S.

[Communicated by Sir Charles Lyell.]

(Read November 9, 1870 *.)

IT has long been known that strata of Coal and Mountain Limestone are found in Bear Island; but the true geological conditions of this island were first ascertained by Professor Nordenskiöld, who visited it with the Swedish expedition of 1868. He and Professor Malmgren collected a large number of fossil plants out of the coal and the associated rocks. These plants, according to Nordenskiöld, point to the following relations of the strata:—

Mountain limestone.	Siliceous schists.
	Productus-limestone with large, thick-shelled species of *Productus*.
	Spirifer-limestone with gypsum. Many *Spiriferi*, some of them of colossal size.
	Cyathophyllum-bearing limestone and dolomite.
Sandstone with intercalated coal and clay-shale. Contains the plants.	
Russian-island limestone. Greyish yellow dolomite with beds of calcareous shales.	
Red Devonian (?) shales.	

The plants, therefore, were found under the Mountain Limestone. The Russian-island limestone contains no determinable fossils; and its geological position is therefore doubtful, as is also that of the red shales, which last Nordenskiöld is inclined to place in the Devonian. The plants lie partly in the coal itself, partly in the sandstone, and partly in the dark-coloured shale, which in some places is quite filled with plant-remains. They are all land-plants; no trace of marine plants or animals is to be found. The whole deposit containing the plants is therefore probably of freshwater origin; and the coals,

* See Quart. Journ. Geol. Soc. vol. xxvii. p. 1.

in any case, owe their origin entirely to land-plants. The number of species of plants is inconsiderable in proportion to the large number of specimens which Nordenskiöld and Malmgren have collected. I received the following species:—*Calamites radiatus*, Br. (*C. transitionis*, Göpp.), *Cardiopteris frondosa*, Göpp. sp., *C. polymorpha*, Göpp. sp., *Palæopteris Rœmeriana*, Göpp. sp., *Sphenopteris Schimperi*, Göpp., *Lepidodendron Veltheimianum*, Sternb., *L. commutatum*, Schimp. (*Ulodendron*), *L. Wickianum*, Hr., *L. Carneggianum*, Hr., *Lepidophyllum Rœmeri*, Hr., *Knorria imbricata*, Sternb., *Kn. acicularis*, Göpp., *Cyclostigma Kiltorkense*, Haught., *C. minutum*, Haught., *Halonia tuberculosa*, Brgn.?, *Stigmaria ficoides*, Sternb., *Cardiocarpum punctulatum*, Göpp., and *C. ursinum*, Hr.,—in all eighteen species, of which only three have not yet been discovered in other places. The greater number of the plants, and all the most abundant forms, belong to known, and partly to widely spread species, and thus furnish us with the means of comparing this flora with those of other lands, and of the different subdivisions of the coal-formation. It contains three species in common with the *Coal-measures*; but of these *Lepidodendron Veltheimianum* is the only one of importance; for the determination of *Halonia tuberculosa* is not certain, and the *Stigmariæ*, consisting only of rhizomes of different plants, do not afford sufficient data for a comparison of species.

The flora of Bear Island differs, therefore, much from that of the Coal-measures, but quite as much on the other hand from that of the Devonian. If we compare it with the flora of the *Cypris*-shales of Saalfeld, in Thuringia, which belong to the Upper Devonian, we do not find a single species in common. Altogether the Devonian flora of Germany has no species in common with Bear Island; for the statement that *Calamites radiatus* occurs in the Devonian is only founded on its presence at Kunzendorf, in Silesia, which locality belongs rather to the Lower Carboniferous than to the Devonian.

With the Lower Carboniferous flora the relations of that of Bear-Island are quite different. Of the eighteen species, fifteen occur in other localities in the Lower Carboniferous formation, ten in the Mountain Limestone, and nine in the Millstone-grit. It cannot, therefore, be doubted that the Bear-Island flora belongs to the Lower Carboniferous series. If we compare it carefully with fossil deposits of other lands, even neglecting the stratigraphical relations of the rocks containing the plants, it is clear that it has the greatest resemblance to the flora of the sandstones and shales lying immediately under the Mountain Limestone, and that it forms a distinct stage (étage) of the Lower Carboniferous, constituting a passage into the Upper Devonian. We may call this stage the Bear-Island or Ursa stage (Ursa-Stufe).

To this Ursa-stage belong the following plant-bearing localities:—Kiltorkan, and generally the Yellow Sandstones and Carboniferous Shales of the south-west of Ireland; the Greywacke of the Vosges and the southern Black Forest; the Verneuilii-shales of Aix, and St. John's in New Brunswick (Canada). As several of these have till now been regarded as Upper Devonian, it will be necessary for me to confirm this classification in detail. I have discussed it more fully in my treatise, which will be published by the Swedish Academy, and have illustrated the plants in fourteen plates.

The Yellow Sandstone of Ireland is well known to lie immediately under the Carboniferous Shale, which, in its turn, is covered by the Mountain Limestone. It is regarded as the Upper Old Red, and, as such, is classed with the Devonian. But the flora of the Yellow Sandstones of Kiltorkan and the shales of Tallowbridge quite contradict this classification. I owe to the kindness of Messrs. W. H. Baily and Robert H. Scott a collection of plants from these localities, which have enabled me to make a comparison. It contains, from Tallowbridge, *Calamites radiatus*, *Lepidodendron Veltheimianum*, and *Knorria acicularis*; and, from the Yellow Sandstone of Kiltorkan, *Calamites radiatus*, in large pieces, *Cyclostigma kiltorkense*, *C. minutum*, *Lepidostrobus Bailyanus*, Schimp., *Lepidodendron Veltheimianum*, *Stigmaria ficoides*, and *Palæopteris hibernica*, Forb. sp., to which also *Sphenopteris Hookeri*, and *S. Humphriesiana* may be added.

The flora of Tallowbridge therefore, so far as it is known, agrees very nearly with that of Kiltorkan; and both of them coincide in a remarkable manner with that of Bear Island; for, of the ten Irish species, five or six are common to the latter. *Palæopteris hibernica*, of which beautiful fronds are found at Kiltorkan, has not yet, it is true, been discovered in Bear Island; but the nearly allied *Palæopteris Rœmeriana*, Göpp. sp., has been found there; *Calamites*, *Lepidodendron*, and *Knorria* are represented by important common species; and the two *Cyclostigmata*, which were formerly known only from the south of Ireland, reappear in the distant Bear Island. The complete agreement of such a relatively large number of species at such far distant localities, these species being besides of such frequent occurrence as to be true typical plants, leaves hardly any doubt that these floras must have belonged to the same epoch in time.

We have already seen that the Bear-Island flora is so nearly related to that of the Mountain Limestone and the Millstone-grit, that it must be classed with this and not with the Devonian. Therefore the flora of Kiltorkan must also belong to the Lower Carboniferous, and we must draw the line of separation between the Devonian and the Carboniferous below the Yellow Sandstone. It follows necessarily that the overlying Carboniferous shales must belong to the Lower Carboniferous, to which they are also more nearly allied by their marine remains than to the Devonian, as appears from the lists which Mr. Baily has published. The fish-remains from Kiltorkan present the only difficulty; for they agree more with those of the Old Red: but so long as no species are found which are decidedly identical with those of the Old Red of Scotland, these fish-remains can by no means be said to contradict the classification founded on the plants of the Yellow Sandstone of Kiltorkan, which confirms the published views of Sir R. T. Griffith, Prof. Haughton, and Mr. Symonds. These fish-remains only show that some genera, which were formerly regarded as belonging exclusively to the Old

Red, pass up into the Ursa stage of the Lower Carboniferous, represented, however, probably by other species than in the Old Red of Scotland. This happens also among the plants; and among the lower animals, not only many genera, but even numerous species pass up from the Devonian to the Mountain Limestone.

It is much to be regretted that the plants of the Marwood beds, and the Lower Carboniferous flora of England and Scotland generally, have been so imperfectly studied. They would certainly furnish very valuable materials for the decision of the much-vexed question where the limits are to be drawn between the Devonian and the Carboniferous in Devonshire.

On the Continent the flora of the Greywacke of the Vosges and of the southern Black Forest belongs to the Ursa stage. Of the twelve Vosges species which Prof. Schimper has described, nine occur in Bear Island, and four have been recognized in Ireland. *Calamites radiatus*, as in Bear Island and in Ireland, is very common, and forms, together with the *Lepidodendra, Stigmariæ,* and *Knorriæ,* the chief mass of the plants.

At Moresnet, in the neighbourhood of Aix, immediately under the Carboniferous Limestone, occurs a shale which rests upon the Eifel Limestone. This shale yielded *Palæopteris Rœmeriana,* and *Spirifer disjunctus,* Sow., and was entitled by Herr von Dechen the Verneuilii-shale, and placed at the uppermost limit of the Devonian. As, however, this *Spirifer* is also present in the Carboniferous shales of Ireland *, and therefore passes up from the Devonian into the Lower Carboniferous; and as we meet with the fern among the plants of Bear Island, we may probably class these Verneuilii-shales of Aix with the Ursa stage, and draw the dividing line with all the more reason below them, since they lie in unconformable stratification upon the Eifel Limestone.

Among the American fossil floras, that of St. John's, New Brunswick, belongs, according to my view, to the Ursa stage, and not to the Devonian, in which Dawson has placed it. Dawson's list ('Acadian Geology,' p. 534) contains forty-eight species; of these, thirty-seven have not been found elsewhere, nine are known in the Carboniferous, and three in the Devonian. The greater number, therefore, of those which are common to other localities belong to the Carboniferous; and it is remarkable that two of the Devonian species are only represented by a few leaf-fragments, and their determination may be still doubtful; while among the Lower Carboniferous species the Calamites are very abundant, and *Calamites radiatus* in some places fills whole strata, and is therefore quite as abundant as in Ireland, Germany, the Vosges, and in Bear Island. To this it may be added that, among the thirty-seven species of St. John's which as yet have not been found elsewhere, twelve agree so nearly with Carboniferous species as to be only di-

* [This *Spirifer disjunctus* was stated, in the Memoir of Salter and Baily relied upon by Prof. Heer, to have occurred in the Carboniferous strata of that country; but this has since been ascertained by Mr. Etheridge to have been a mistake.]

stinguished from them with great difficulty. For example, the most abundant fern of St. John's, *Pecopteris discrepans*, Daws., is hardly to be distinguished from *Pecopteris lonchitica*, a species which, both in America and in Europe, is abundant in the Carboniferous. In the same manner, *Cordaites Robbii*, Daws., is so near *C. borassifolius*, Sternb., sp., that, according to Dawson, it may often be mistaken for it; and *Asterophyllites parvulus*, Daws., is scarcely distinguishable from *A. delicatulus*, Sternb. (*Bechera*). Therefore the St.-John's flora has in fact the character of the Lower Carboniferous formation, and the only question is whether it does not approach more nearly to the Millstone-grit flora (with which it has five species in common) than to the Ursa stage. By this also it becomes doubtful whether the Catskill and Chemung groups do not belong rather to the Ursa stage than to the Upper Devonian.

In the arctic zone, besides the Bear-Island flora, we may regard the sandstones of Parry Island as belonging to the Ursa stage. In Melville Island also the sandstone lies under the Mountain Limestone; and the *Knorria acicularis*, which is found in it, serves as a point of contact with the Bear-Island flora, and shows that these plants of South Ireland and the Vosges reached as far as 76° N. lat.

If we add the plants of St. John, Kiltorkan, the Vosges, the south Black Forest, and the Verneuilii-shales to those of Bear Island, they yield to the Ursa stage a flora of seventy-seven known species, of which three are common to the Devonian and seven to the Middle Carboniferous. Of the former, however, one, and of the latter three species are doubtful, either in their determination or in their geological position. With the Upper Carboniferous (the Permian) the Ursa stage has not a single well-determined species in common; with the Mountain Limestone it has thirteen species, and with the Millstone-grit twelve; and with the two united, eighteen species. Among these are the most frequent species, such as form the true typical plants of the Lower Carboniferous, namely *Calamites radiatus, Lepidodendron Veltheimianum, Knorria imbricata, Cardiopteris frondosa*, and *C. polymorpha*. One of the most characteristic genera of the Ursa stage is *Cyclostigma*.

The flora of the Mountain Limestone and its equivalents appears to be less rich than that of the Ursa stage; the culmiferous beds, on the contrary, have yielded a large number of plants, as have also the Greywacke and *Posidonomya*-shales of the Harz, Silesia, and Moravia. If we compare the plants from these different places, we find in each a number of peculiar forms, which probably arises from the flora being, as yet, so little known to us; but we find also many species in common, which throughout are the most abundant and consequently the most important of the localities. These are chiefly the typical plants mentioned above. The Millstone-grit flora, when compared with that of tho Ursa stage, is remarkable for the increase in the number of species common to the Coal-measures; among these are species which have a wide range through the formation, such as *Neuropteris Loshii* and *Calamites Suckowii*. The newer Greywacke, also, which forms a passage to the Coal-measures, is distinguished from them by the character of its flora. Among the ferns, the Pecopterids are wanting or very rare, as they are in all the Lower Carboniferous of Europe; the different forms of Cyclopterids and of the fine-leaved Sphenopterids, on the contrary, are very frequent and characterize the fern-flora of this period. In the Coal-measures, on the contrary, the genera *Neuropteris* and *Pecopteris* (including *Cyatheites* and *Alethopteris*) are developed in a variety of species, and appear everywhere in great abundance. *Lepidodendron* extends through the Lower and Middle Carboniferous, but on the whole is more abundant in the former, while the *Sigillariæ,* which play so important a part in the Coal-measures, are almost entirely wanting in the Lower Carboniferous. In fact, the whole flora of the Lower Carboniferous period must have had a different aspect from that of the Coal-measures, although it consisted of the same families and, in a great measure, of the same genera.

If we now glance once more over the Lower Carboniferous strata of Bear Island, we cannot fail to recognize a striking resemblance between them and the formations of the same age in Europe, especially in the south of Ireland. We may classify them in the following manner.

		Bear Island.	South Ireland.	Other localities.
Lower Carboniferous.	III. Mill-stone-grit stage.	Siliceous schists.	*Posidonomya*-shales and coal.	Culmiferous in Devon; Millstone-grits, Upper Greywacke and *Posidonomya*-shales in the Harz, Silesia, and Moravia.
	II. Mountain-Limestone stage.	*Productus*- and *Spirifer*-limestone.	Limestone formation with *Productus* and *Spirifer*.	Burdie House; Mountain Limestone and shales in Silesia; Hainichen, Ebersdorf, Artinsk, Petrowskaja, &c. in Russia; Parry Island, Spitzbergen.
	I. Ursa stage.	*Cyathophyllum*-limestone.	Carboniferous shale with *Cyathophyllum*.	Barnstaple.
		Sandstones and shales with plants.	Yellow Sandstone with plants.	Greywacke of the Vosges and the southern Black Forest; Marwood plant-bed (?), St. John's, in Canada; Sandstone of Melville Island, Catskill and Chemung?
Doubtful.		Russian-Island Limestone.	Upper Old Red.	
Devonian.		Red shales.	Old Red.	*Cypris*-shales of Saalfeld.

The Coal-measures are wanting in Bear Island, as in Spitzbergen;

but probably the siliceous schists, which are greatly developed in the upper divisions of the Mountain Limestone, represent the Culm or Millstone-grit. The position of the Russian-island limestone, which is widely spread, especially in Spitzbergen, is still doubtful; for determinable fossils are wanting in it; and the classification of the red shales in the Devonian is by no means certain. But although much still remains doubtful, we can see from clearly established facts that a remarkable and analogous development must have taken place in South Ireland and in Bear Island, high up in the north, and in the middle of Europe, in the formation of the rocks as well as in the plants and animals contained in them. Therefore the flora of the Ursa stage is of great significance in the history of the earth, as we shall see still more clearly if we cast a glance at the position which it holds in the order of the earth's development.

In the Silurian and Lower Devonian all the known plants and animals are marine; and it is not until the Middle and Upper Devonian that land-plants, indicating dry land, make their appearance. Yet at present there are only a few localities known to us, which may be designated as Devonian islands: the neighbourhood of Saalfeld, in Thuringia, which belongs to the Upper Devonian, is the only one which has yielded a fairly respectable number of plants; and even these have been found mostly in small fragments, which probably may have been divided into too many species. Towards the end of the Devonian period the dry land increases rapidly in the northern hemisphere; it must have been a time of rising of the bed of the sea. With this great formation of dry land begins a new epoch—the Carboniferous. The first division of this I have called the Ursa stage. With it came in the first rich land-flora, which can be traced in the northern hemisphere, both of the Old and New World, from 47° to 74° and 76° N. lat. Everywhere it exhibits the same character; everywhere appear *Calamites radiatus* (which probably clothed the marshy low country with its long column-like stems), the branching *Lepidodendron*, thickly clothed with leaves, and the curious *Knorria*. Even the *Cyclostigmata*, with which we have become acquainted in Ireland and Bear Island, were probably not wanting in dry-land formations lying between them, and formed part of the woods under whose shade the species of *Cardiopteris* and *Palæopteris* spread out their powerful fronds.

This flora already comprises such a remarkable number of species, many of which appear in such widely distant regions, that it seems to indicate a wide-spread continent which was situated in the temperate as well as in the arctic zone. The coal-lands of Russia reached perhaps as far as Bear Island, the plants of which would then represent the most northern offshoots of the Russian Lower-Carboniferous flora. That the Ursa stage must have belonged to a land of considerable extent is shown by the freshwater animals found in it, the great pond-mussels (*Anodonta*) and the insects (all Neuroptera). They could only have lived in a land large enough to give rise to lakes and rivers.

It is difficult to decide how long this state of things lasted. Then

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the land began once more to sink; and brackish-water formations appear, followed later on by purely marine deposits. The Carboniferous shales and Mountain Limestone cover the former land with its imbedded plants. The great extension of the Mountain Limestone over many parts of Europe and America, and the small number of land formations which it covers, show us that this sinking of the land must have been a general phenomenon. The northern hemisphere must therefore most probably have had quite a different aspect at that time than during the Ursa stage. Then the same phenomenon recommenced as in the beginning of the Carboniferous period. In consequence of an extended rise to the west we obtain the continental formations of the Millstone-grit, which afterwards reached their greatest extent and development in the Coal-measures. During this long lapse of time the flora remained, on the whole, the same. Many of the leading species outlived all the mutations, and show that the whole of the land was never under water, even at the time of the formation of the Mountain Limestone; there always remained enough dry land to support these species of plants, which afterwards extended their range when the land, as in the Millstone-grit, began again to have a greater extension. There can be no doubt that a long period must have elapsed between the beginning of the Ursa stage and the Millstone-grit, and that during these many thousand years the conditions of life of the organic beings must have undergone reiterated changes. It is therefore a very remarkable fact that, in spite of this, so many species lasted through this time and did not undergo any perceptible alteration. The many forms of *Calamites radiatus* which appear in Bear Island are also found in the lowest member of the Lower Carboniferous and in the roofing-slates of Moravia; then the species disappears, nor does any similar form of this type (which Schimper has raised into a separate genus, *Bornia*) extend into the Coal-measures; the same thing takes place in the species of *Knorria* and *Cardiopteris*. These facts tell very decidedly against the continuous and imperceptible transmutation of plant-species. They are the more important, since the plants on Bear Island must clearly have lived under quite different conditions of light than those in the Vosges or in Ireland; for they must have endured a long winter-night. It is indeed remarkable that evergreen trees, such as the *Lepidodendra* must probably have been, and plants with such large leaves as *Cardiopteris frondosa* could have withstood such a long winter-night, even if we take into consideration that the Bear-Island flora consisted almost entirely of vascular Cryptogams, which can better dispense with light than the Phanerogams. Moreover the climate of Bear Island must have been as favourable to the growth of plants as that of Ireland or the Vosges, although that island lies $26\frac{1}{2}°$ further north; for the corresponding species are as large and quite as luxuriantly developed, and have even produced more considerable coal-strata than those of lower latitudes in the same period. Warmth, therefore, must at that time have been more equally distributed over the earth, whilst already in the Miocene period a great difference had begun to arise, which has increased immensely up to the present time. The climate must have been not only more equable, but warmer, as is shown by the coral-banks which were formed at that time in Spitzbergen, as well as by the enormous tree-like Cryptogams and the large-leaved ferns which Bear Island produced.

APPENDIX.

On CYCLOSTIGMA, LEPIDODENDRON, *and* KNORRIA, *from* KILTORKAN. By Prof. OSWALD HEER, F.M.G.S.

[PLATE IV.]

(Read January, 10, 1872*.)

1. CYCLOSTIGMA KILTORKENSE, Haught. Ann. & Mag. Nat. Hist. ser. 3, vol. v. p. 444.

Stem clothed with a finely wrinkled bark. It is covered with numerous and very close striæ; and these very fine striæ pass away into spiral lines, and are in some places joined together. When the outer bark is wanting we have only these fine striæ. Such a specimen I received as *C. Griffithi*, Haught.

On the bark there stand in regular rows small round warts, which have a circular depression at the top. These are surrounded by a projecting rim, which is often striated with fine cross lines. Sometimes these warts look like small hollows having a smooth middle part. The warts are about 2 millims. in diameter. They are from 8 to 13 millims. apart, and form highly oblique transverse rows. Pl. IV. fig. 5*a* is a piece of a stem; 5*b* a portion with the wart, magnified.

Branches.—These agree entirely with the stems in the formation of the bark and in the warts. The bark is also wrinkled and covered with very fine and close striæ. The warts are from 6 to 8 millims. apart, and in a branch 13 millims. broad there are two or three in the oblique row (fig. 4, and, a portion enlarged, fig. 4*b*).

As remains of fruit-cones, which Schimper has described as *Lepidostrobus Bailyanus* (Traité de Paléontologie Vegét. ii. p. 71), are often found near the stems of this species, they probably belong to it. In support of this view is the fact that in Bear Island also the cone-scales have been found near the fragments of the stem (see my 'Fossil Flora of Bear Island,' pl. xi. fig. 3*c*). These cones differ from those of *Lepidodendron* in their firm and almost woody base, which is marked with a longitudinal furrow, and in the remarkably long bristle-like front portion.

2. CYCLOSTIGMA MINUTUM, Haught. *ibid.* p. 444.

Lepidodendron minutum, Haught. Journ. Geol. Soc. Dublin, vol. i. p. 235.

Lepidodendron, sp., Lyell, Elements of Geol. ed. 6, p. 521, fig. 585.

* See p. 85 of the present volume.

Sigillaria dichotoma, Haught. *ibid.* p. 234 (but not p. 235, which certainly belongs to *Lepidodendron*).
Filicites dichotoma, Haught. *ibid.*

This is distinguished from *C. kiltorkense*, 1st, by the smaller and more approximated leaf-scars (warts); 2ndly, by the absence of the fine, close, longitudinal striæ; 3rdly, by the strongly prominent transverse striæ; 4thly, by the distinct central scar of the warts. These differences are not to be seen only in the specimens from Kiltorkan, but also in those from Bear Island (see my 'Fossil Flora of Bear Island,' pls. xi. & xii. figs. 11 & 12, enlarged 11*b* & 12*b*).

The Stem (fig. 3).—This specimen has a breadth of 33 millims. The leaf-scars, 1 millim. broad, stand close together; for they are only from 1 to 1½ millim. apart. It has very distinct transverse striæ, which in part run over the whole width of the stem; with these there are also longitudinal striæ, which, however, stand further apart and are more irregular and deeper than in the former species. The scars are partly circular, partly oval; they are sharply defined, with a projecting rim and a central wart. The transverse rows (as represented in the bough figured by Lyell) are almost horizontal, tolerably widely separated from each other, in consequence of the pressure undergone by the stem, while the scars have drawn near to each other, by which means they apparently receive an almost whorled position, which in fact Haughton has ascribed to the *Cyclostigmata*.

Branch.—The branch shown in fig. 2 is 11 millims. in breadth, and is divided in the upper part into two branches of almost equal thickness. The scars have a breadth of 1 millim., and, as on the stem, are about 1 to 1½ millim. apart. They are circular, very sharply defined, with a distinct projecting rim and central wart. Here also we have irregular transverse striæ and also the shallow longitudinal striæ. Between these the bark is quite flat, and the finer striæ of the former species are wanting. That this cannot be a branch of *Cyclostigma kiltorkense* may be seen by a comparison with fig. 4 and fig. 5*c*. These last are branches of *C. kiltorkense*, which are distinguished from those of *C. minutum* by the characteristics given above. We have therefore branches and stems of *Cyclostigma minutum* (fig. 3) and branches and stems of *C. kiltorkense*; of these last I have figured one in fig. 5*a*. There are, however, some twice as thick.

3. Knorria acicularis, Göpp., var. *Bailyana*.

Knorria Bailyana, Schimper, Paléont. Végét. ii. p. 48.

The specimen figured (fig. 6) agrees so well with *Knorria acicularis*, Göppert, in the slender linear pointed warts (see Göpp. Nova Act. Acad. Leop. Carol. 1852, p. 200, pl. xxx. fig. 3, and Heer, 'Fossil Flora of Bear Island,' pl. x. figs. 6, 7) that I thought myself justified in referring it to that species. It differs from the specimens from Bear Island and Silesia only in the more closely approximated warts, which are somewhat more pressed together. This difference appears to me of no importance, as *Knorria imbricata* (of which *Knorria acicularis* is perhaps only a variety) also occurs with more or less approximated warts. Schimper, who set much value upon this difference, has separated the species as *Knorria Bailyana.* Opinion is known to be much divided as to the relation of *Knorria* to *Lepidodendron.* Göppert, in his first work on the plants of the transition rocks, made twelve species of *Knorria,* but afterwards reduced them to one, placing most of them with *Lepidodendron Veltheimianum*; whilst Geinitz and Schimper hold *Knorria imbricata* to be a distinct plant. The numerous specimens from Bear Island have inclined me to this view, which I have dwelt upon more fully in my 'Flora of Bear Island.' It is true that Schimper connects with *Knorria Bailyana* (with a query) the fruits which I refer to *Cyclostigma,* and also (again with a query) the *Cyclostigma minutum,* Haught., of which he has only received very fragmentary pieces. It may, indeed, be a question whether our *Knorria* is not a peeled *Cyclostigma.* This does not appear to me very probable—because, in the specimens figured by me in figs. 2 and 3, single portions are peeled; under this bark, however, we by no means have *Knorria.* We see, indeed, in fig. 3, the impression of the inner bark, but *no Knorria-structure,* and just as little in fig. 2. That it is not only the bark which we have here, but pieces of the whole stems and branches, we see from the thick masses of coal, and because in some places the impression of the warts at the back is to be seen.

4. Lepidodendron Veltheimianum, Sternberg.

The specimen represented in fig. 1 is from Tallowbridge; but I received a similar one from Kiltorkan. It is only the impression of a short fragment of a branch; and as in this the leaf-scars are not so beautifully and sharply defined as in the stems, the exact determination is very difficult. We recognize upon the branch very closely approximated leaf-scars, which touch each other at the margins. They are rhomboidal, longer than they are broad. Inside them we have an oblong or obovate depression, pointed at the base (magnified in fig. 1 *b*). The cicatricula is not preserved. In their form and thick-set position these leaf-scars resemble those of the branches of *L. Veltheimianum*; but a more certain determination cannot be made from the present specimens.

I received this specimen as *Lepidodendron elegans,* Haught. A *L. Griffithii,* Brongn., is not known to me. As far as I know, Brongniart has nowhere described a species under this name. The formation of the bark is so very different from that of *Cyclostigma,* that it cannot be a branch of the same tree. On the contrary it may be a question whether the *Cyclostigmata* may not be roots or, more properly speaking, rhizomes of *Lepidodendron.* It may be alleged that they remind us forcibly of the *Stigmariæ,* which are now pretty generally considered to be rhizomes or root-formations, and connected either with *Sigillaria, Lepidodendron,* or *Knorria.* So long, however, as no traces are found of such a connexion between *Cyclostigma* and *Lepidodendron*, we are not justified in uniting *Cyclostigma* to *Lepidodendron*.

These are the grounds which have led me to treat the *Cyclostigmata*, *Knorriæ*, and *Lepidodendra* of the Yellow Sandstone of South Ireland as separate species. I have formed my opinion from careful research upon the specimens sent me from Tallowbridge and Kiltorkan; and I think I have found better and sharper characteristics for the two species of *Cyclostigma* than have yet been known; for, indeed, in some degree, satisfactory representations of each of them have been till now wanting. I do not know any transitions which would establish a connexion of these different plant-remains; therefore I have no right to unite species made not by myself but by others. I will not dispute the possibility of the connexion, as I know well the gaps in our knowledge of the ancient floras; but proofs of it must first be afforded before we can accept it.

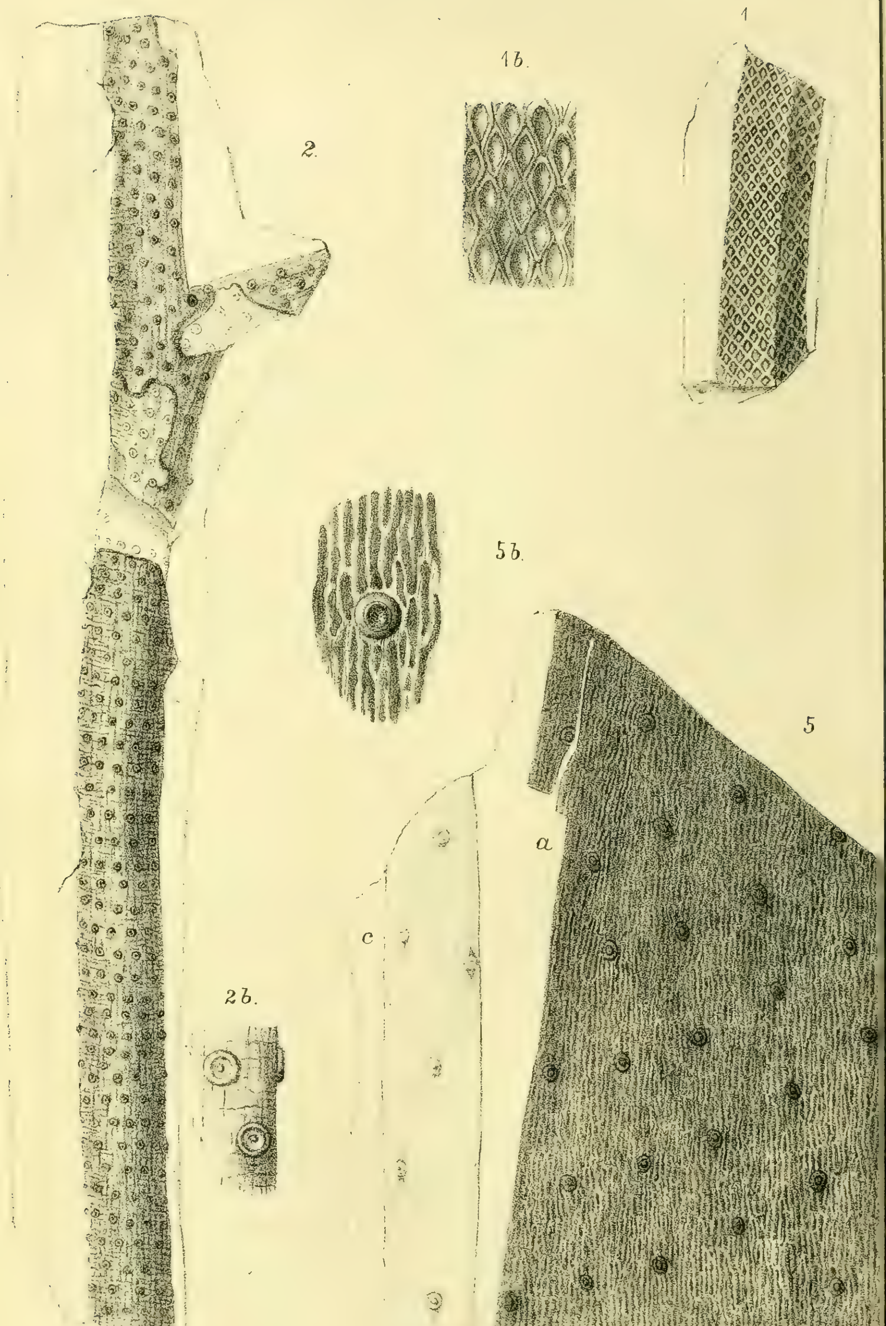
I have left out of consideration the *Stigmariæ* of Kiltorkan and Tallowbridge, as the position of the *Stigmariæ* is especially doubtful. The few specimens which I have received from Ireland have large, tolerably close-set scars; and near them lie root-fibres like those present in *Stigmaria ficoides*. This form agrees with the specimens I have received from Bear Island and figured in pl. xii. of my 'Bear-Island Flora.' The *Stigmariæ* are now generally regarded by palæontologists as the roots of *Sigillaria*. Schimper, however, unites one form with *Knorria imbricata*, Geinitz, and another with *Lepidodendron Veltheimianum*. So long as it is not determined to which plants these rhizomes belong, we must give them under separate names.

EXPLANATION OF PLATE IV.

Fig. 1. Fragment of a branch of *Lepidodendron Veltheimianum*, Sternb., from Tallowbridge; 1*b*, a portion, magnified.
2. Branch of *Cyclostigma minutum*, Haught., from Kiltorkan; 2*b*, a portion, magnified.
3. Portion of the stem of *Cyclostigma minutum*, Haught., from Kiltorkan.
4. Branch of *Cyclostigma kiltorkense*, Haught., from Kiltorkan; 4*b*, portion, magnified.
5. *Cyclostigma kiltorkense*, Haught., from Kiltorkan; *a*, fragment of the stem; *b*, a portion of *a*, magnified; *c*, fragment of a branch.
6. *Knorria acicularis*, Göpp., from Tallowbridge.

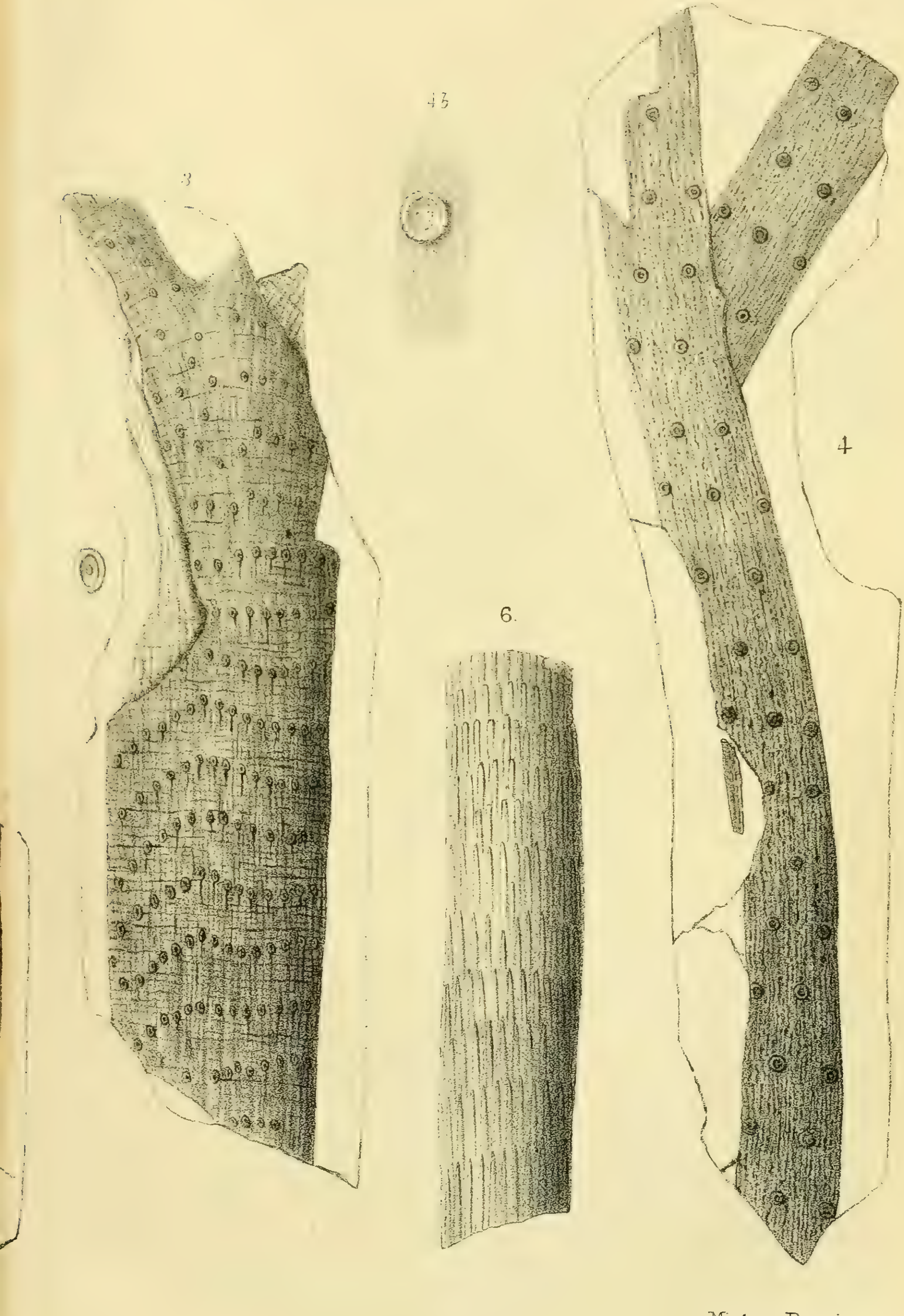
Discussion.

Mr. Carruthers was glad that he had made the observations which he did on Prof. Heer's former Paper, as it had caused the Professor to give the reasons on which his opinions were based. He was doubtful whether the success which had attended Prof. Heer's determination of species from leaves justified the application of the same principles to mere stems. He could not accept the difference in size or distance of leaf-scars as a criterion of species, inasmuch as they were merely the result of the difference in the age and size of the parts of the plants on which they were observed.



G.H.Ford. R.Mintern.

CYCLOSTIGMA, LEPIDODENDRO[N]



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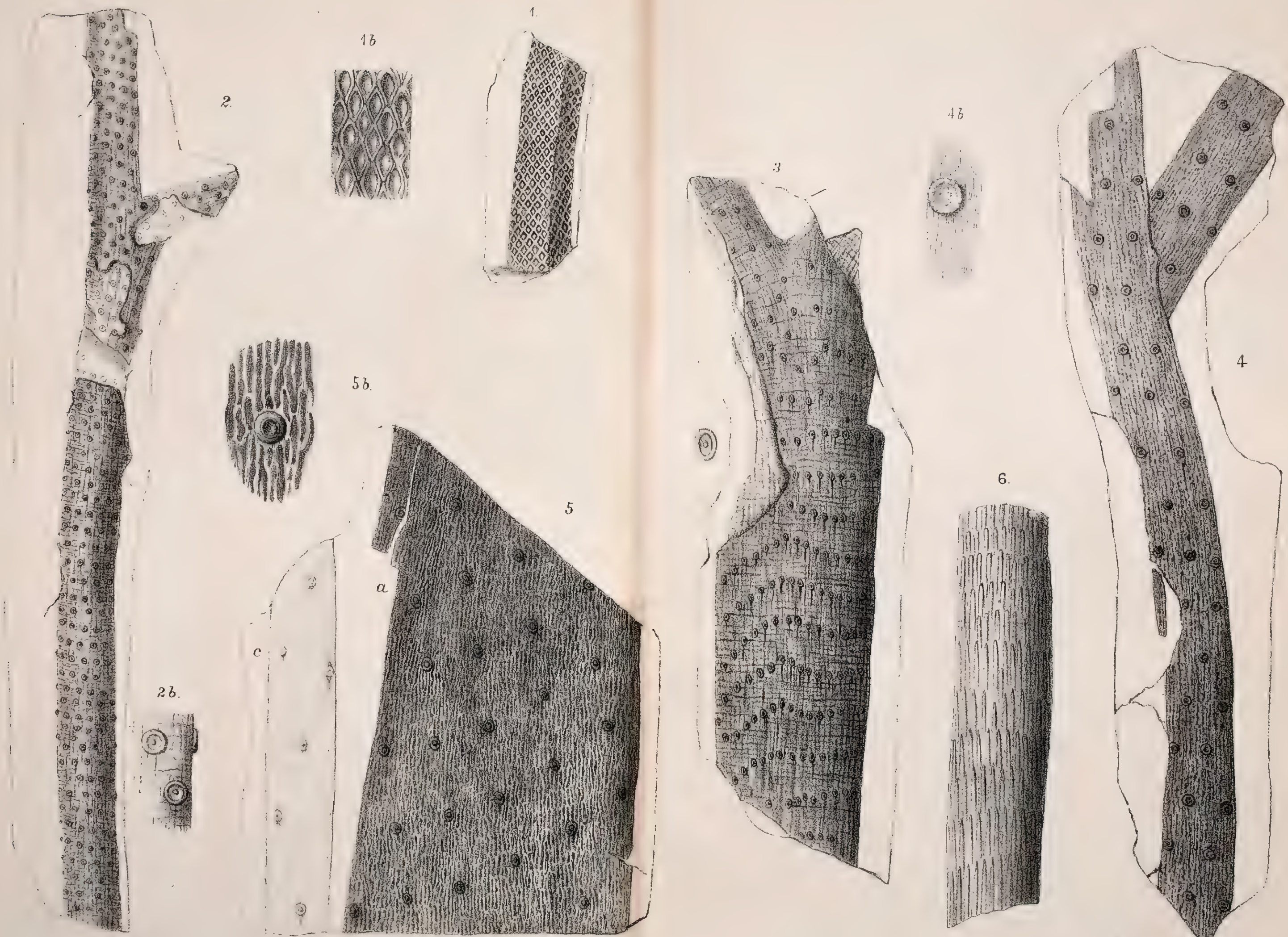
AND KNORRIA FROM KILTORKAN.



G. H. Ford. R. Mintern.

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CYCLOSTIGMA, LEPIDODENDRON AND KNORRIA FROM KILTORKAN.

Even Prof. Heer himself had united together specimens presenting greater differences in this respect than those which he distinguished. He considered *Cyclostigma kiltorkense*, *C. minutum*, and *Lepidodendron Veltheimianum* to be founded on different parts of one species. In the Kiltorkan fossils the outer surface of the original stems was often broken up into small fragments, the phyllotaxy on which proved them to be portions of large stems, and not entire branches. As to *Knorria*, it was certainly the interior cast of the stem of *Lepidodendron*, with casts of the channels through which the vascular bundles passed with some cellular tissue to the leaves; and the specimen figured showed that it belonged to a branch similar to that represented as *C. minutum*. He considered that the four supposed species ascribed to three genera, were only different forms of the same plant.

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2. *On some* Undescribed Fossils *from the* Menevian Group. By Henry Hicks, Esq., F.G.S. *With a* Note *on the* Entomostraca, by Prof. T. Rupert Jones, F.G.S.

[Plates V.–VII.]

(Read December 6, 1871*.)

In continuation of the descriptions of the fossils from the Menevian group which have at different times appeared in the 'Journal' of the Geological Society, I propose now to add those forms, which though frequently referred to in our communications, have hitherto remained undescribed. So far as present researches have gone, these will also complete the fauna of the Menevian group as exhibited in Wales. The additions made to the fauna of the Cambrian rocks (Longmynd and Menevian groups) by these researches, include no less than fifty-two new species, belonging to twenty-three genera. The following Table shows to what orders these belong, and in what proportion they occur in these early rocks.

Trilobites....................	10	genera including	31	species.
Bivalve crustaceans..........	4	,, ,,	4	,,
Brachiopods	4	,, ,,	6	,,
Pteropods	3	,, ,,	6	,,
Sponges	1	genus ,,	4	,,
Cystideans	1	,, ,,	1	,,

If we now add to these the annelids which had been previously discovered in these rocks, we have at least seven orders represented in this fauna, the earliest at present known. These same groups are also more or less present and tend to characterize these early deposits wherever found; but no country has up to the present time produced a more varied fauna or a greater richness in types than England. Scandinavia has a larger number of species, but not so many groups. On referring to the Tables in M. Barrande's excellent work on

* See p. 41 of the present volume.

Trilobites, lately published, we find the following results given, with reference to those forms discovered in the lowest or Paradoxides zones in different parts of the world. The groups are those given by him in the Tables.

	Bohemia.	Spain.	Scandinavia.	England.	America.
Trilobites	27	9	77	33	26
Other Crustaceans	......	......	......	1	......
Ostracoda	......	1	5	4	......
Annelids	......	......	......	4	......
Pteropods	5	......	2	7	......
Gasteropods	......	2	......	......	......
Brachiopods	2	6	8	6	6
Bryozoa	1	......	4	......	......
Cystideans	5	1	......	1	1
Sponges	......	......	......	2	......
	40	19	96	58	33

From this Table it will be observed that England has produced eight of these groups, whilst none of the other countries has yielded more than five. It is, however, most interesting to note the similarity of types in regions so far apart, and the close resemblance of the faunas. Though animal life was restricted to these few types, yet at this early period the representatives of the several orders do not show a very diminutive form, or a markedly imperfect state, nor is there an unusual number of blind species. The earliest known brachiopods are, apparently, as perfect as those which succeed them; and the trilobites are of the largest and best-developed types. The fact also that trilobites had attained their maximum size at this period, and that forms were present representative of almost every stage in development, from the little *Agnostus* with two rings to the thorax, and *Microdiscus* with four, to *Erinnys* with twenty-four, and blind genera along with those having the largest eyes, leads to the conclusion that, for these several stages to have taken place, numerous previous faunas must have had an existence, and, moreover, that even at this time, in the history of our globe, an enormous period had already elapsed since life first dawned upon it. The following are the species now to be described.

Agnostus davidis, Salter. Pl. V. figs. 2–4.
Brit. Assoc. Report, 1865.

This is the largest species found in the Menevian group, being about $\frac{5}{8}$ inch long. Head rounded and forming about two thirds of a circle, and about $\frac{3}{8}$ inch wide. Surrounded by a narrow border. The glabella occupies about one third of the width, and tapers forwards. It is divided at the base of the anterior third by a transverse furrow, into an anterior spheroidal lobe and a posterior elongated lobe, the anterior part of which is raised centrally; there is a triangular lobe on either side at the base of the glabella. Cheeks slightly raised, and gibbous.

Thorax depressed, strongly trilobed; pleuræ grooved deeply to the tips. Axis trilobed, the central lobe being largest and pyramidal in shape. The two lateral lobes triangular in shape.

Tail of the same shape as the head, but more strongly margined. The axis is large, and occupies more than a third of the width, reaches backwards to within a short space of the posterior margin, and is indented by three furrows on each side, each running obliquely backwards from the centre, which is somewhat raised.

Locality.—Menevian group: St. David's; and near Dolgelly, North Wales.

Agnostus Eskriggei, Hicks. Pl. V. fig. 7.

About $\frac{1}{6}$ of an inch long. Head and tail each nearly circular in form, highly convex, and with a smooth surface. Glabella indistinctly marked by short lateral furrows.

Thorax compressed, not so wide as the head.

The axis of the tail is equal to about half of the width, nearly circular in form, and exhibits no distinct furrows.

Locality.—Menevian group: St. David's; and near Dolgelly, North Wales.

Agnostus scutalis, Salter. Pl. V. figs. 9–14.
Brit. Assoc. Report, 1865.

This is the most plentiful species found in the Menevian group. It seldom exceeds $\frac{1}{2}$ an inch in length, though some of the specimens are lengthened by pressure to rather over $\frac{1}{2}$ an inch. The general form of the head and tail about two thirds of an oval, highly convex and strongly trilobed, also strongly marginate. Glabella long and narrow, occupying rather less than a third of the width of the head, and tapering slightly; it is divided by a transverse furrow into two lobes—an anterior of spheroidal shape, and a posterior elongated lobe which supports a tolerably strongly marked tubercle; a pair of triangular lobes lie at the base of the glabella. The cheeks are covered with small tubercles.

Joints of the thorax strongly raised, axis trilobed, and pleuræ deeply grooved.

Tail nearly of the same shape as the head; axis equal to about a third of the width. The axis is of about equal width for the upper half, and then tapers to a sharp point from which a groove runs to the posterior margin; it is divided into three lobes, the anterior stretching as a narrow band across, the second transversely lozenge-shaped, with a centrally raised tubercle, and the hinder one pyramidal. The lateral lobes of the tail are disconnected by means of the terminal furrow, and like the cheeks are covered with tubercles.

Locality.—Menevian group: St. David's and near Maentwrog and Dolgelly.

Agnostus scarabæoides, Salter. Pl. V. fig. 8.

It is $\frac{3}{4}$ inch long, Head and tail rounded to rather less than two thirds of a circle, and surrounded by a narrow margin; surface depressed; head rather wider than long. Glabella pyramidal in shape, and divided about its anterior third by a transverse furrow into two lobes. The anterior lobe is almost triangular in shape; and it differs in this respect from any other of the Menevian species. A pair of small triangular lobes lie at the base of the glabella. The cheeks are covered with rather strong tubercles. Thorax undeterminable.

The axis of the tail wide, somewhat pyramidal in shape, and indented by three furrows on either side. The anterior furrows are short and run obliquely inwards, marking off somewhat triangular lobes on either side. The other furrows extend across, and bound a transversely lozenge-shaped lobe, which bears a tubercle. The side lobes of the tail are, like the cheeks, covered with tubercles.

Locality.—Menevian group: St. David's.

AGNOSTUS BARRANDEI, Salter. Pl. V. figs. 5 & 6.
Brit. Assoc. Report, 1865.

Oval in form, highly convex, and rather less than half an inch in length. Very slightly marginate, and with a smooth surface. Glabella rather indistinctly marked out by two faint lateral furrows, less wide than the cheeks, and extending in length to about half of the head. Thorax raised, axis strongly lobular, and pleuræ grooved.

The axis of the tail is equal to about a third of the width. It is grooved into an anterior pair of triangular lobes, into a wide middle lobe, which runs across, and into a posterior triangular lobe. In the groove at the base of the triangular lobe there is a rather strongly raised tubercle.

Locality.—Menevian group: St. David's.

ARIONELLUS LONGICEPHALUS, Hicks. Pl. V. figs. 20–26.

This species is somewhat like the *Arionellus ceticephalus*, Barrande, and forms another important link in the connexion between British and Bohemian primordial faunas.

It is rather longer than the Bohemian species. The length of the perfect specimen must have been rather over an inch and a half; width about equal to a third of the length; oval in form and convex. Head large; length about equal to width at base, and strongly convex. Glabella conical in shape, prominent, and marked by four furrows on each side. Eye small and remote from the glabella, situated towards the outer margin, and rather farther back than half the length of the head. The anterior facial sutures run forwards in a line with the general axis—and the posterior sutures backwards, to cut across the hinder margin a little to the inner side of the angle, and in a line with the terminal ends of the pleuræ. The axis tapers backwards; the pleuræ, 16 in number, are deeply grooved and have blunt extremities; the fulcrum is situated at about a third of the length from the axis. The axis of the tail is well raised, and composed of three annulations, the hinder one being pyramidal in shape. The side lobes are grooved by furrows.

Locality.—Menevian group: St. David's; and near Maentwrog, North Wales.

Erinnys venulosa, Salter. Pl. VI. figs. 1–6.
Brit. Assoc. Report, 1865.

Ovate in form, being widest in front, and surface depressed. The largest specimens indicate a fossil at least 3½ inches long.

Head semicircular, margined all round, but with no posterior spines, wider than the body. Glabella small, occupying only about two thirds of the length and about one fifth of the width of the head, pyramidal in shape, slightly raised, and indented by three pairs of furrows; the hinder ones reaching backwards nearly to the neck-lobe, and marking off triangular lobes on each side.

There are no distinctly marked eyes or facial sutures; but a tolerably strongly raised ridge strikes off on each side from opposite the upper glabellar lobes towards the posterior angles, reaching nearly ⅔ of the distance across. From these ridges lines strike off in each direction, especially forwards, dividing and subdividing in their course, and giving a veined character to the whole surface.

Thorax composed of 24 rings; axis narrow, convex, and tapering towards the tail; pleuræ compressed, grooved, and, including the spines, more than twice as long as the rings of the axis; spines bent backwards from the fulcrum, at which part the surface becomes suddenly raised into a sharp transverse ridge.

The tail is semicircular, and has a tolerably strong axis, composed of four segments. The lateral lobes are marked by four moderately well defined ribs.

Locality.—Menevian group: St. David's, South Wales; and Waterfall Valley, near Maentwrog, North Wales.

Carausia, gen. nov.

Gen. char. Ovate in form and moderately convex. The head occupies about two fifths of the whole length, is more convex than the body, margined, and, without the posterior spines, nearly semicircular in form. The spines extend backwards to about a third of the length of the body, but point outwards, so that at their extremities they are separated from the body by a space equal to about half the length of the opposite pleuræ. The glabella occupies less than a third of the width and about two fifths of the length of the head; it is more convex than the cheeks, and is separated from them by deep lateral furrows, but indistinctly so anteriorly. Two furrows indent the glabella on each side. There is no appearance of eyes or facial sutures; but, as in *Erinnys,* a ridge extends across from the glabella towards the outer margin, giving off branches in its course, which again subdivide, until a veined appearance is given to the whole surface. In the single specimen found 15 rings of the thorax only are preserved; and from general appearance this would seem to be near the full number. The axis is strongly raised, and less in width than the lateral lobes. The pleuræ are deeply grooved, and produced into tolerably long spines, which are longer in the upper and middle pleuræ than in the lower ones.

Tail?

This genus resembles in some respects *Holocephalina,* and in others

Erinnys, having, indeed, a somewhat intermediate character. From the former, however, it differs in having a large and well-marked glabella, and a veined instead of a punctated surface to the cheeks, and in the larger number of thoracic segments; from the latter in having long head-spines, a shorter glabella, a smaller number of segments to the body, and short spines to the hindmost pleuræ.

CARAUSIA MENEVENSIS, sp. nov. Pl. VI. fig. 7.

The characters of the species are those of the genus, as only one species is known at present.

Locality.—Menevian group: Porth-y-rhaw, St. David's.

HOLOCEPHALINA INFLATA, spec. nov. Pl. VI. figs. 8–10.

Ovate in form, and surface well raised. Length about $\frac{1}{2}$ inch, width about $\frac{1}{4}$ inch. The head is nearly semicircular in form, highly convex, and punctated all over. The glabella is small, and indistinctly marked off from the cheeks by faint lateral furrows. A strong nuchal spine extends some distance backwards. There is no appearance of the wide head-margin, nor of the strong angular spines of *Holocephalina primordialis.* The body appears to have consisted of not more than ten rings. The pygidium is semicircular, with a strongly raised axis of three segments; and the lateral lobes bear three ribs, strongly raised, almost spinous, near the margin.

Locality.—Menevian group: St. David's.

CONOCORYPHE HOMFRAYI, Salter. Pl. VI. fig. 12.

Length about $3\frac{1}{4}$ inches, breadth $1\frac{1}{2}$ inch. Form ovate. Head semicircular, marginate, and produced posteriorly at the angles into short thick spines. Glabella parabolic, slightly convex, and showing two pairs of rather indistinct furrows. It occupies about a fourth of the width and two thirds of the length of the head. The cheeks are less convex than the glabella, and their surface is smooth. The eyes are small, and situated near the glabella, but unusually far backwards towards the neck-furrow.

The thorax consists of 14 rings. The axis is considerably narrower than the lateral lobes, slightly convex, and tapering gradually towards the tail. The pleuræ are long and deeply grooved, and with the fulcrum situated about midway in the length.

The tail is semicircular, and bounded by a margin. The axis is raised and composed of two segments. The lateral lobes are marked by a pair of ribs on each side.

Locality.—Found by Mr. D. Homfray, of Portmadoc, in Menevian beds of the Waterfall Valley, near Maentwrog, North Wales.

CONOCORYPHE CORONATA, Barr. (*Conocephalites coronatus*). Pl. VI. fig. 11.

This specimen was discovered by Mr. Homfray in the same beds with the former species, in the Waterfall Valley, near Maentwrog. It is the only Bohemian species yet found in the Menevian group, and is therefore interesting as forming a link between the two faunas. It is perhaps rather smaller in size than the specimens figured by Barrande, but in all other respects it appears to be identical with his species.

Anopolenus impar, nov. sp. Pl. VII. figs. 1–7.

In none of the specimens found were the free cheeks attached to the head; but the position of the sutures indicates that, when present, the head must have been semicircular in form, with two tolerably long spines reaching backwards from the posterior angles. The glabella reaches to the margin in front, is rounded anteriorly, and is widest at the base of the frontal lobes. It occupies more than a third of the width of the head, and is raised somewhat above the level of the cheeks, from which it is separated by tolerably deep lateral furrows. It is grooved by one complete and two incomplete lateral furrows, and one pair of small anterior furrows. The hinder furrow and the neck-furrow are strong and remote from one another. The inner cheeks are narrow, and bounded on the outside along their whole length by the eye-lobe, which is wide and flexuous, and on the inner side for the lower two thirds by the cheek-lobes, which are well marked in some of the specimens. The outer cheeks are narrow, and have long posterior spines attached. The thorax consists of 14 segments; axis wide and tapering. The anterior pleuræ are shorter than the rings of the axis, and are scarcely, if at all, spinous at the ends. The three hindmost pleuræ, however, have very long spines, which bend backwards, and reach on each side beyond the extremity of the pygidium.

The tail consists of a wide, raised and tapering axis of four or five segments, extending nearly to the posterior margin, and of a furrowed, strongly margined limb, serrated on the outer edge. This species is distinguished from *Anopolenus Salteri* by having wide, flexuous eye-lobes, very narrow inner cheeks, a rounder anterior border to the glabella, wider axis to the thorax, and a stronger and longer axis to the tail. Its narrow inner cheeks and wide flexuous eyes distinguish it also from *Anopolenus Henrici*.

Locality.—Menevian group: St. David's; and Maentwrog, North Wales.

Anopolenus Salteri, Hicks. Pl. VII. figs. 8–11.
Quart. Journ. Geol. Soc. vol. xxi. p. 478.

In the Quart. Journ. Geol. Soc. vol. xxi. a detailed description of this species is given, along with a restored figure compiled from the fragments then discovered. Since then, however, other and more perfect specimens have been found, which show that, though for the most part the figure there given is correct, yet a few points need alteration. The specimens now figured indicate that the glabella was narrower, and tapered sharply anteriorly—that the free cheeks were not cut off abruptly, but continued in a line with the posterior margin, as in *A. impar*—and that the axis of the tail was longer.

Locality.—Menevian group: St. David's.

Cyrtotheca hamula, Hicks. Pl. VII. fig. 14.

A curved Pteropodous shell, nearly $\frac{1}{2}$ inch long and $\frac{1}{6}$ of an inch wide at the upper part, and gradually tapering backwards. It suddenly bends at the junction of the terminal third, still diminishing in size, and at last attaining to a sharply pointed apex. A longitudinal ridge extends along the surface of the sides near the centre; but the surface otherwise is tolerably smooth. The mouth is somewhat funnel-shaped, but with one lip greatly elongated. The shell itself, which is to a certain extent preserved, seems to have much of the same texture as that of a *Lingula*.

Locality.—Menevian group: St. David's.

STENOTHECA CORNUCOPIA, Salter. Pl. VII. figs. 12 & 13.

A curved shell, sufficiently distinct from any other fossil found n the Menevian group to indicate a new and interesting genus. A small and wide form, with the lines of growth strongly marked on its surface. About $\frac{1}{8}$ of an inch in length and about $\frac{1}{15}$ of an inch in width at the upper part.

Locality.—Menevian group: St. David's.

THECA PENULTIMA, Hicks. Pl. VII. figs. 15 & 16.

This species differs from the other species in the Menevian group in having strongly marked lines of growth, which are always straight and not curved forwards as in *Theca corrugata*, and also in having one wide and tolerably strongly raised longitudinal ridge running along the surface of its sides.

Locality.—Menevian group: St. David's.

THECA STILETTO, Hicks. Pl. VI. figs. 18 & 19.

This species is of smaller size than the other two in the Menevian group; it has also a smooth surface, with no indications of the lines of growth visible. It tapers also much more suddenly, and attains a sharper point than either of the others.

Locality.—Menevian group: St. David's.

PROTOCYSTITES MENEVENSIS, Hicks. Pl. V. fig. 19.

At present very little is known of this species; but to complete the fauna of the Menevian group, so far as it is discovered, these fragments are now figured. An arm and some indistinct plates are shown.

Locality.—Menevian group: St. David's.

During my researches at St. David's I have, from time to time, endeavoured to note the range of the genera and species as they were discovered; and the results have been given in the several Tablse published in the 'Journal' of the Geological Society and in the British Association Reports. I have not, however, been able to obtain much evidence by this means to support the theory of colonies propounded by the eminent palæontologist M. Barrande; but several very interesting facts have been noted, which it might be well again to refer to. The Brachiopods here, as in other formations, have a greater range than any of the other fossils, the same species extending in some cases through the whole Cambrian series. The Sponges come next; for *Protospongia fenestrata* occurs in the Longmynd group, in the Menevian group, and again in the Upper Lingula flags, to the base of the Tremadoc rocks, where it was found by me a few years since when examining these rocks in North Wales. These therefore continued to live on during the deposition of from 8000 to 10,000 feet of strata. None of the other Menevian species have any considerable range; and but very few of the genera pass beyond the Menevian boundary. Out of ten genera of Trilobites, one only, the little *Agnostus*, passes upwards*, and not one species out of the whole number, in all twenty-nine. Indeed the range of all these species is very limited; and each one seems to mark a special zone, where it flourished for a time and then disappeared, perhaps to be followed by others of the same type, but never to reappear. The Crustacea are therefore, in these earliest rocks, the surest indices of the age of the strata, and the best guides in defining the several zones; for the more perfect the forms and the higher the development, the less likely are they to have a great range.

It seems difficult to conceive that distinct and separate creations should so frequently take place; and yet how strange that, up to the present time, no satisfactory cause has been assigned for this constant dying out of old forms and replacement by new ones! It seems possible to conceive that physical conditions should occasionally produce sudden destruction or disappearance, for a time, of particular forms, and a recurrence with a reappearance of the same conditions—as for instance when a sudden elevation of a portion of the sea-bottom took place, forming a beach or shallow water, and then became again depressed. But when we have an even deposit, with some of the forms continuing while others are dying out and new ones coming into the field, we must look for other than physical conditions, and for some cause hitherto unexplained. Evidences of frequent oscillations of the sea-bottom during the deposition of the Cambrian rocks are of common occurrence in North and South Wales. The results obtained by the examination of the successive strata in the neighbourhood of St. David's may be briefly summed up thus†:—

1. A pre-Cambrian island, composed of quartziferous beds interstratified with dark green sandstones, and with a strike from N.W. to S.E., and hence discordant with that of the overlying Cambrian strata. This is possibly one only of a group which existed at this period in this neighbourhood; for another occurs, under almost the same conditions, about eight miles from St. David's, and surrounded by beds much like those at St. David's.

2. Fine-grained quartziferous hornstones of a bright green colour, with a strike from N.E. to S.W., and resting on the sides of, but not overlying, the pre-Cambrian island. During the deposition of these

* *Conocoryphe* also is mentioned; but I agree with Mr. Belt in thinking that the so-called *Conocoryphe* of the upper rocks is generically distinct from the Menevian ones.

† I have already given the thickness of each division at p. 391, Quart. Journ. Geol. Soc. vol. xxvii.

rocks the island must have been situated in a deep sea; and the fine-grained beds could then have been produced from an admixture of the rock composing the island, or of a rock somewhat similar in character. These rocks are not seen in contact with the island at all places; but there is evidence to show that they have been faulted downwards at these parts. I am not quite satisfied that there is not a break here in the strata; for though the strike is nearly the same as in that of the overlying beds, yet there does not appear to be true conformability.

3. Conglomerate composed of quartz pebbles, with a purplish matrix, indicating a shore-deposit. Masses of rock similar to the green beds of the island are also present; and the whole might easily have been formed out of parts similar to portions of the island now visible. The purplish colour could easily arise out of the green under another state of oxidation of the iron; for the frequent alterations shown in these lower rocks from purple to green and red, even in the same bed, make this matter of colour of little importance.

4. Greenish micaceous sandstones, with ripple-markings on the surface, and indicating shallow-water or shore-deposits. Worm-burrows and holes are common in these sandstones; and at present they are the only indications found of the existence of life at this period.

5. Finer-grained red flaggy beds, sometimes, however, of a bright green colour. Here we have plentiful indications of the presence of animal remains. These beds were apparently deposited in moderately shallow water not far from shore. Brachiopods are abundant, as also some small bivalved crustaceans. Some fragments of a trilobite also have been discovered in these beds.

6. A great thickness of purple and green sandstones and grits, with the surface of the beds frequently ripple-marked. These were evidently deposited in shallow water, or formed a sea-beach. The only evidence of animal life found at present in these beds consists of worm-burrows and holes, which occur very generally throughout the whole series.

7. A varying series of beds, at first gritty and of a yellowish colour, with also some fine conglomerate, then greenish and of finer grain, and afterwards red and purple sandstones. The finer beds here, as before, yield the greatest number of fossils and the greatest variety of forms. Between the grit-beds in the first part of this series there are some thin bands of very fine shale, which must have been made up of a muddy deposit, probably washed down by a river; and on these we have those markings figured in pl. xvi. vol. xxvii. of the Quart. Journ. Geol. Soc. which I have named *Protospongia? major*. It is really doubtful at present what these are; and I am sorry the figures do not quite show their true character, as, instead of being simple lines, they should indicate flattened fibres, as described in the same paper, p. 401. Possibly they are impressions of the fibres of sea-weed only; whilst, on the other hand, there are some facts, such as the thinness of the bands frequently interstratifying very rough grit, to indicate a possibility of their being brought down by a river

during floods along with the muddy deposits, and so spread out along a shore. They certainly appear as if broken up; for none of the fibres appear perfect.

8. The beds of the Menevian group now come in, at first gritty and of a grey colour, and rather unfossiliferous, then becoming darker in colour and of a finer grain, and at last almost a fine black slate. Most of these beds must have been deposited in deep water, as they are not accompanied by sandstones until the very last, near their junction with the Lingula-flags. In the finer beds fossils are very plentiful, and there is also a corresponding increase in the variety of forms.

9. The true Lingula-flags, a series of sandstones and shales, occasionally ripple-marked. Very barren for the most part, and showing a return to shore-deposits.

These successive changes, producing such varied conditions of deposit, must have had much to do with causing barrenness in parts of the strata, and with the appearance, on the other hand, of successive zones of animal life. The continuation of the same genera through a great thickness of shore or shallow-water deposits, as is the case in the Longmynd and Lingula-flags, and the rapid dying out and shorter range of the genera in finer beds or deep-sea deposits, like the bulk of the Menevian group, are interesting facts, and deserving of consideration when we seek for natural laws to account for the conditions presented to us at these early periods.

Note *on the* Entomostraca *from the* Cambrian Rocks *of* St. David's.

By Prof. T. Rupert Jones, F.G.S.

1. Leperditia Hicksii, Jones. Pl. V. fig. 16 (reversed and imperfect).

Small, ovate; hinge-line short; posterior margin broadly curved, anteriorly rather narrower. Ocular spot indicated by a subovate, smooth, and faintly depressed area, reaching up to the hinge-line. Muscle-spot marked (on one side) by a faint irregular subcentral depression, whence a branching vein-like line of bright pyrites[*] runs downwards nearly to the ventral border. Surface mostly punctate by the exposed cellular structure of the test, which has been converted into iron-pyrites, and nearly bared of its outermost layer.

This is the smallest *Leperditia* I know, and differs from others chiefly in its very nearly oval outline, and in the relative largeness of its eye-spot.

The still smaller *Primitia solvensis* was at first classed as a *Leperditia*, but has been subsequently referred to a more appropriate genus.

The above-described old Cambrian *Leperditia* is here named after its discoverer.

2. Entomis buprestis. Pl. V. fig. 15.

Leperditia bupestris, Salter, Brit. Assoc. Rep. 1865, Trans. Sect. p. 285.

L. punctatissima, Salter, Siluria, 1865, Appendix, p. 519.

This is nearest to *Entomis divisa*, Jones (Monthly Microsc.

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L. punctatissima, Salter, Siluria, 1865, Appendix, p. 519.

This is nearest to *Entomis divisa,* Jones (Monthly Microsc.

Journ. Oct. 1870, pl. lxi. fig. 12), but differs from it chiefly in the furrow being nearly vertical across each valve, instead of following a curve. The furrow on the specimen is defined, though faintly, on one of the valves, and it is marked by symmetrical fracture on each*. The beauty of the pitted pyritous valves is striking, but not uncommon, especially in Carboniferous bivalved Entomostraca. The shape is evidently a very elongate ovate; but the borders are partly imbedded. Numerous oval flaky spots on the same little slabs indicate, perhaps, other similar but obscure fossils.

Locality. Porth-y-rhaw: St. David's.

3. LARVAL TRILOBITE? Pl. V. figs. 17 & 18†.

Leperditia? *vexata*, Hicks. Quart. Journ. Geol. Soc. vol. xxvii. p. 396.

These specimens are univalved orbicular carapaces, with a central ridge, to some extent resembling *Cyclus* in character; but they have no transverse furrow. The little posterior lobes and the straight continuance of the central ridge are peculiar as compared with any published figures, but only sufficient, I think, to indicate that we have before us the larval form of some Trilobite.

Locality. Porth-y-rhaw: St. David's.

4. Mr. Hicks has also sent me some specimens from the red rocks at the base of the Cambrian strata in the St. David's promontory, which he thinks belong to a new genus, somewhat allied to *Cyclus*. The little irregularly orbicular surfaces of these natural casts rarely seem to present any special features; but in one case a slight transverse line appears to divide the area unequally, and the anterior (?) smaller portion is again traversed at right angles by a faint line. A trace of granulation is the only other feature; but nothing is present to enable me to offer any definite opinion on these interesting relics of primæval life.

From these rocks Mr. Hicks has also obtained specimens of another form, to which he has given the provisional name of *Leperditia*? *cambrensis* (Quart. Journ. Geol. Soc. vol. xxvii. p. 401, pl. xv. figs. 15–17). I have seen the specimens, and can only regard them as undeterminable.

EXPLANATION OF PLATES V.–VII.

(Illustrative of fossils from the Menevian group of Wales.)

PLATE V.

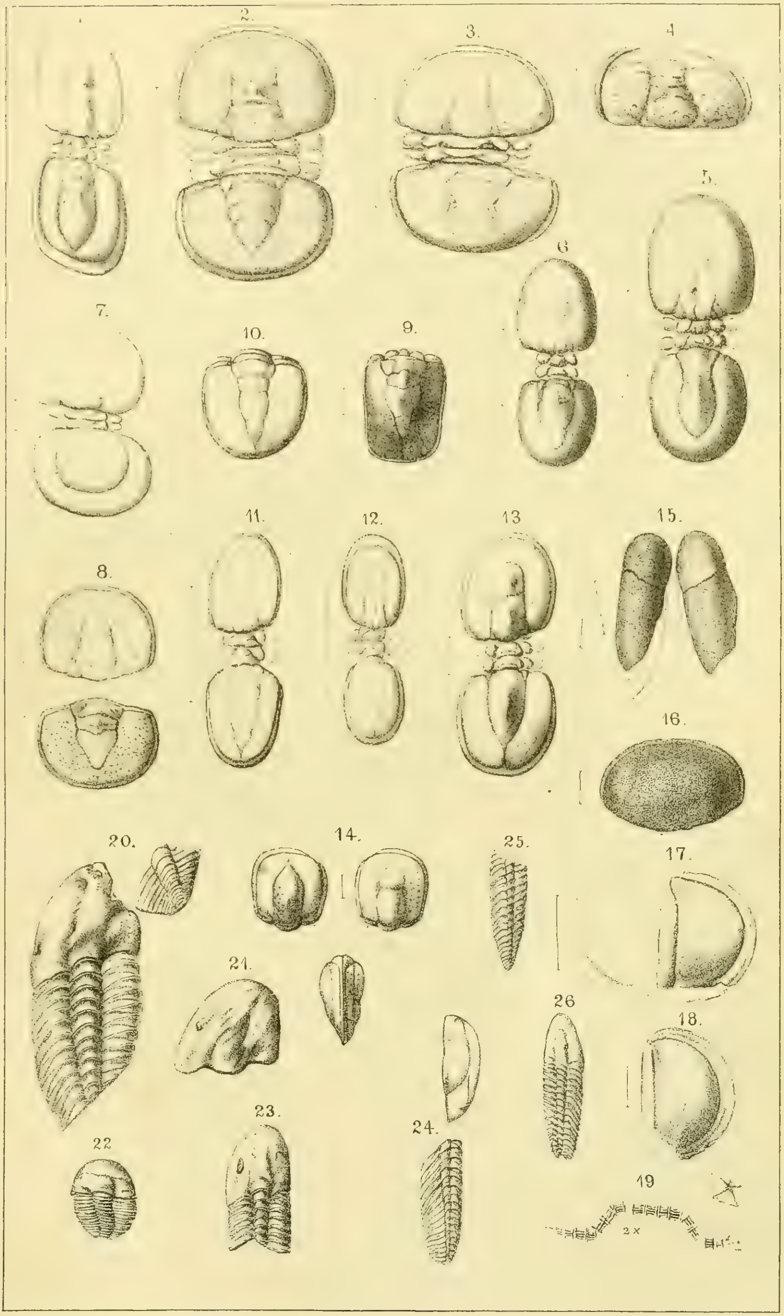
Fig. 1. *Agnostus cambrensis*, Hicks. Enlarged. This specimen is more perfect than the ones figured in Quart. Journ. Geol. Soc. vol. xxvii. pl. 16. It was found at the base of the Menevian Group, at Porth-y-rhaw, St. David's; and it is one of the few fossils which reach from the Harlech (or Longmynd Group) to the Menevian Group.

2–4. —— *davidis*, Salter. Enlarged. From Porth-y-rhaw, St. David's.

5 & 6. —— *Barrandei*, Salter. Enlarged. Obtained from the lower beds of the Menevian Group, at Pempleidu, St. David's.

* Drawn rather too strongly in the figure.

† Reversed, and the small posterior lobes not well expressed.



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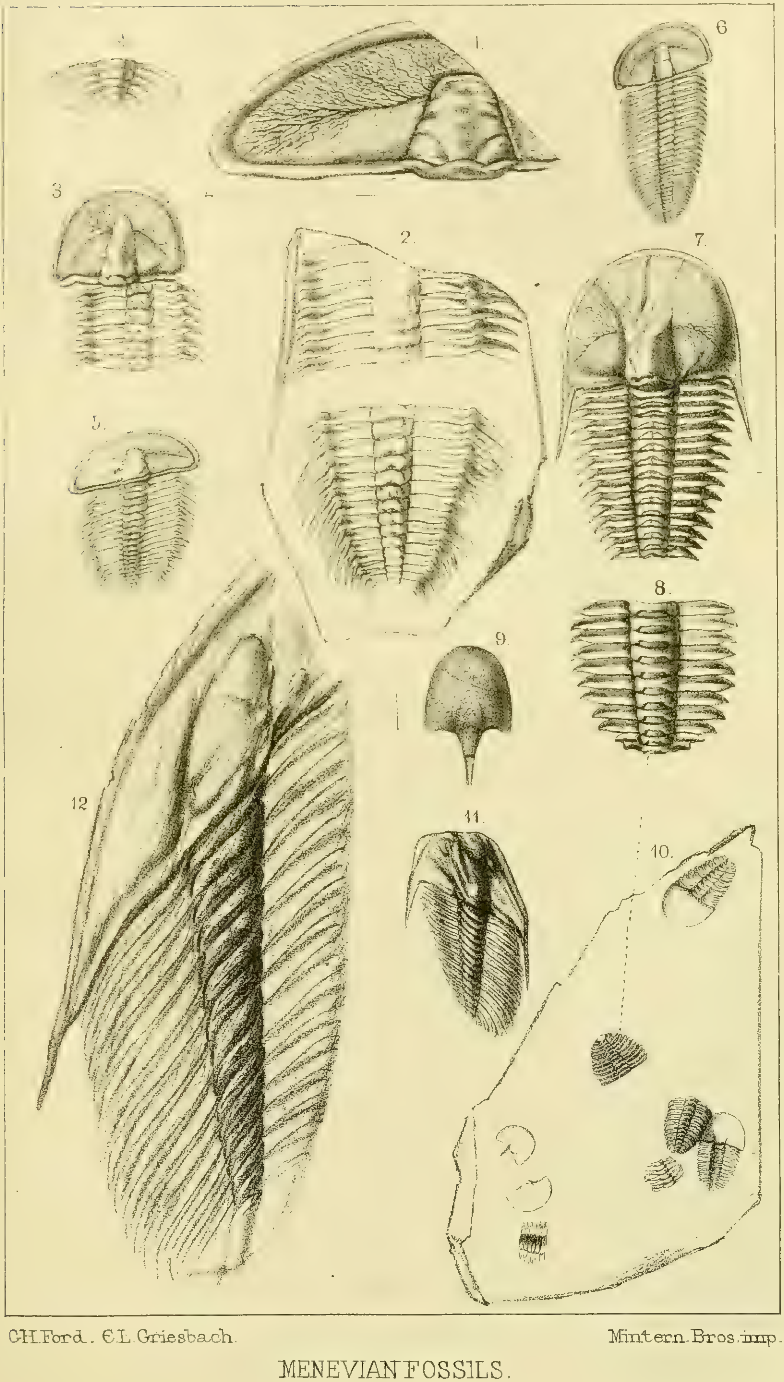
MENEVIAN FOSSILS.



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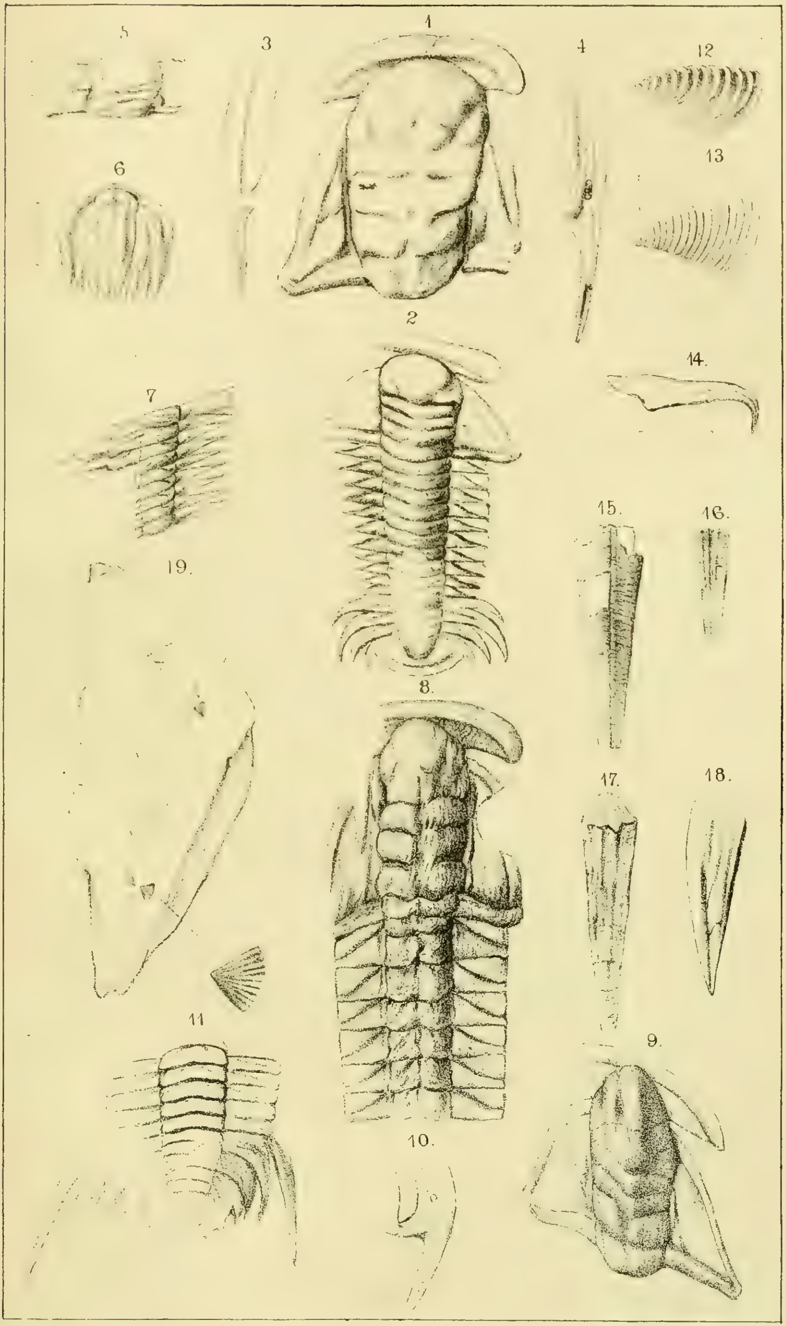
MENEVIAN FOSSILS.



G.H. Ford. C.L. Griesbach. Mintern Bros. imp.

MENEVIAN FOSSILS.

Fig. 7. *Agnostus Eskriggei*, Hicks. Enlarged. Porth-y-rhaw, St. David's.
8. —— *scarabœoides*, Salter. Enlarged. Ditto.
9–14. —— *scutalis*, Salter. Enlarged. Ditto.
15. *Entomis buprestis*, Salter, sp. Enlarged. Ditto.
16. *Leperditia Hicksii*, Jones. Enlarged. Ditto. (Drawing reversed and imperfect.)
17 & 18. Enlarged. This peculiar and rather doubtful fossil is not at all uncommon in the middle beds of the Menevian Group, and is frequently surrounded by a black carbonaceous-looking substance. Occasionally it is found in the interior of a small black nodule. This would tend to bear out the view that it belongs to the embryonic stage of some of the larger Trilobites.
19. *Protocystites menevensis*, Hicks. Enlarged. From Porth-y-rhaw, St. David's.
20–23. *Arionellus longicephalus*, Hicks. Ditto.
24–26. —— ——, Hicks. From near Maentwrog, North Wales (cabinet of D. Homfray, Esq., Portmadoc).

Plate VI.

Figs. 1–4. *Erinnys venulosa*, Salter. From Porth-y rhaw, St. David's. Fig. 1 is enlarged to show the ornamentation on the cheeks.
5 & 6. —— ——, Salter. From the Waterfall Valley, Maentwrog (cabinet of D. Homfray, Esq., and Cambridge Museum).
7. *Carausia menevensis*, Hicks. Enlarged. From middle beds of the Menevian Group, at Porth-y-rhaw, St. David's.
8 & 9. *Holocephalina inflata*, Hicks. Enlarged. The head showing the strong nuchal spine, which, though not restricted to this genus, is yet a characteristic feature.
10. —— ——, Hicks. A group, of the natural size. From a creek west of Porth-y-rhaw, St. David's.
11. *Conocoryphe coronata*, Barrande. Natural size. From the Waterfall Valley, Maentwrog, North Wales (cabinet of D. Homfray, Esq.).
12. —— *Homfrayi*, Salter. Ditto. Ditto.

Plate VII.

Figs. 1–7. *Anopolenus impar*, Hicks. From Porth-y-rhaw, St. David's, and Waterfall Valley, Maentwrog (Cambridge Museum, and cabinet of Mr. Hicks).
8–11. —— *Salteri*, Hicks. From Porth-y-rhaw, St. David's. Fig. 10 is one of the free cheeks, with a portion of the eye-lobe attached. Out of many scores of specimens discovered, in no case have the free cheeks been seen fixed properly to the head; but the sutures are well marked generally, and are sufficiently distinct to indicate the true position and mode of attachment of the loose cheeks, which are found in the same beds with the other fragments.
12 & 13. *Stenotheca cornucopia*, Salter. Enlarged. From Porth-y-rhaw, St. David's.
14. *Cyrtotheca hamula*, Hicks. Ditto. Ditto.
15 & 16. *Theca penultima*, Hicks. Natural size. Ditto.
17. —— *corrugata*, Salter. Ditto. Ditto.
18 & 19. —— *stiletto*, Hicks. Ditto. Ditto. With the operculum magnified.

3. Memoranda *on the most* recent Geological Changes *of the* Rivers *and* Plains *of* Northern India, *founded on* accurate Surveys *and the* Artesian-well Boring *at* Umballa, *to show the* practical application *of* Mr. Login's theory *of the* abrading *and* transporting power *of* water *to effect such changes.* By T. Login, Esq., C.E., F.R.S.E.

[Communicated by A. Tylor, Esq., F.G.S.]

(Read June 21, 1871 *.)

In the appendix attached to this paper will be found a detailed report of the progress made in boring at Umballa; and to illustrate it a section has been made from the published maps of the Grand Trigonometrical Survey of India. From the latter a correct idea can be formed of the shape of the plains of Northern India; while the former gives the nature of the soil below the Himalayan range here at Umballa.

The section passes through the centre of the Doab, commencing at the Military Station of Meerut, and running in nearly a direct north line for 44 miles to where it meets the Dehra and Saharunpore road at $8\frac{1}{2}$ miles beyond the latter station. It then passes along this road in a north-easterly direction, rather oblique to the general fall of the country, where it reaches the foot of the Sewaliks, and passes up the bed of a mountain-torrent, along which the road to the hill sanatorium of Mussoorie runs, passing through the town of Dehra.

This section is therefore some 70 miles east of Umballa, which, again, is about 27 miles west of the watershed line separating the drainage of the Indus from that of the Gangetic valley.

Judging from reviews of the Rigvedas, or ancient Hindoo writings, though the total rainfall is probably the same now as it was 2000 years ago (the sun's heat and the area of sea and land being probably the same), yet, from the probably wooded state of the country in former days, and the perennial streams mentioned in these writings, but now dried up, as for example the Sursoottee (the Saraswati of ancient Hindoo literature), I think we may safely conclude that there has been a great change in the rainfall and the climate of the Punjab within the historic period.

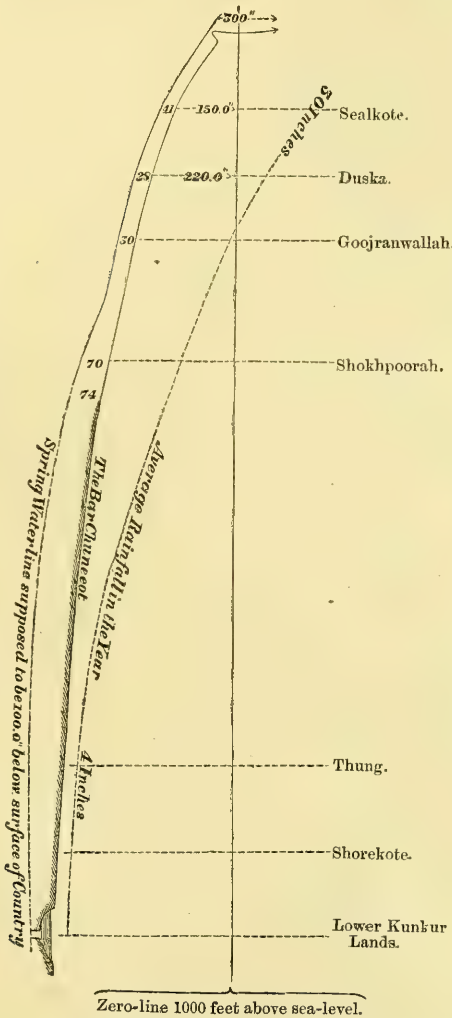
In proof of the correctness of these views I may state that, when engaged on the survey for irrigating the Rechna Doab six years ago, I could not help observing the number of deserted villages all over the plain, where now the rainfall is scanty (in some places hardly six inches in the twelve months); while the depth at which water is reached is excessive, as shown by the following section (fig. 1).

With only thorny scrub jungle almost devoid of foliage over these plains, they are very different from what we find all along the Gangetic valley.

From what I then observed, the conclusion I arrived at was, that these plains were at one time thickly peopled, that a great portion of them was formerly cultivated, and that the rainfall over them must have undergone a great change. These views are con-

* See Quart. Journ. Geol. Soc. vol. xxvii. p. 451.

firmed by the interesting report of the political agent at Babawalpore, which lately appeared in the Supplement of the Punjab Gazette;



Horizontal scale 50 miles to 1 inch. Vertical scale 500 feet to 1 inch.

Fig. 1.—*Section of the Rechna Doab, in the Punjab.*

for in this it is shown, by the existence of the channel of a large stream the banks of which were lined with villages, that a large volume of water must in former days have passed down the river. The selection of such sites for villages goes to show that probably the river was navigable, certainly that it had a perennial stream flowing down it, while at the present day, except after an occasional local rainfall, its bed is always dry.

There can be little doubt therefore, I think, that the river was fed by those streams between the Jumna and the Sutlej which are now lost in the desert and are almost dry during the greater portion of the year. So dry is the Sursoottee at present, that during the religious fair at Zanasur a missionary friend on one occasion saw them, after bunding up the bed below the town, fill this portion of the stream by artificial means with water for the pilgrims to bathe in,—a very heterodox proceeding on the part of a Hindoo; for it is flowing water which is supposed to wash away sins. Had the Sursoottee been thus subject to drying up, it is not reasonable to suppose that it would have been the most sacred river of the Hindoos some 2000 years ago.

Reasoning thus, therefore, we can only conclude that there must have been a great change in the climate, and that there has been a general subsidence of the spring-levels in the neighbourhood of Umballa. Another cause can be assigned for this, namely—that at several places in the district there are remains of embankments carried across the beds and valleys of some of the minor or secondary streams. I designate them thus in contradistinction to those which have their sources among the hills, and are subject to excessive floods. The beds of these mountain-torrents are broad, shallow, and sandy, in some instances level with the surrounding country*. During floods therefore these torrents overflow their banks; and as soon as the transporting power of their water is reduced, a deposit takes place, raising the land on either side of the stream. This overflow spreads in a sheet of water over the plain; and the soil, being light, absorbs a great portion of this water, and the springs are raised thereby, while the remainder of the water passes down these secondary streams in a rather deep narrow channel.

It was across such streams, fed by the local rainfall and this overflow, that bunds were thrown up to store up water, the remains of which may be seen in several directions, as the Executive Engineer of the Northern Division of the Jumna Canal informs me. By not keeping up such bunds the spring levels may be reduced, if from no other cause. What, however, appears to me a still greater reason for the deficiency of water at Umballa is the erection of embankments constructed to prevent this overflowing from the neighbouring streams. In consequence of this the plain on which the station is built is deprived of the natural supply of water which it formerly had; and this causes a still further lowering of the spring-levels,

* A striking example of this is in the case of the Puttri, where this torrent crosses the Ganges Canal. See Sir P. Cautley on the effect of floods in this torrent and their deposits, 'Ganges Canal,' vol. i. p. 157.

[Sir P. Cautley, in company with the late Dr. Falconer, made many excellent observations, not only on the geology of the Sewalik Hills, but on the valley of the Ganges, some of which are recorded in the magnificent work on the Ganges Canal, published by the Indian Government, a copy of which is in the Library of the Geological Society. Mr. T. Login was Assistant-Engineer under Sir P. Cautley. Mr. Login does not agree in all respects with the theoretical views of the "flow of water," expressed in a paper sent by A. Tylor to the Institution of Civil Engineers, February, 1872.—A. T.]

which gives rise, I believe, to the very remarkable phenomenon to be seen at Umballa after a heavy fall of rain—namely, a cracking and subsidence of the ground, forming often chasms large enough to bury a horse or, at times, even an elephant, and which may endanger the public buildings.

This subsidence is, I believe, owing to the water being drained off from between the particles of sand. During a shower, water from some of the surface-drains or any hollow finds a passage to this dry stratum below, and, flowing with considerable velocity to fill the open spaces formerly deprived of water, disturbs the sand, carries some of it forward; and thus a chasm is formed into which the superincumbent earth falls, causing the cracks above mentioned*. How this should be met is a difficult question; and various opinions have been given; but this I do not at present mean to discuss.

What I wish to show is why Umballa is year by year, I understand, becoming more and more deficient of water, which led to the boring of the Artesian well.

It is necessary to point out what is going on at present before attempting to go back to anterior periods; but before quitting this part of the subject and passing to theory, it will be better to state a few more facts regarding the effects now being produced by our mountain-torrents †.

It has been already said that the streams are rapid, broad, and shallow, that during floods they are always overflowing their beds, and depositing the heavier or sandy matter near their banks, while the lighter or clayey matter is carried further towards the secondary streams and is gradually deposited over the plain, so that in time, beds of clay of considerable thickness come to be formed. In the mean time, however, the sandy beds and banks are rising at a more rapid rate; and they rise so high above the neighbouring country that any slight obstruction, such as a few bushes or a tree, might turn the whole course of a large stream. The torrent thus deserts its old channel and takes to the neighbouring low ground through which the secondary class of streams before alluded to flowed. Thus there is very soon a deposit of sand over the clay.

With such an arrangement at work it is evident that one may have alternate strata of sand and clay of irregular thickness; for the torrents which formerly passed down the channels A and B (fig. 2) having raised themselves above the general level of the country, suddenly burst their banks and take to the lower ground at A′ and B′, which in course of time get settled in their turn. Thus in the course of ages we have a general raising of the land above the sea.

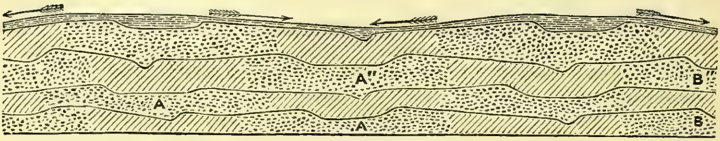
There is still another way in which this irregularity of deposits

* In the June Number of 'Chambers's Journal' I find the following in the "Notes on Science and Art":—"One consequence of drawing away the water is that the land shrinks. In Tynne many of the houses are settling, the bridges are weakened, and the Corn Exchange is sliding from its front. Similar effects of improved drainage have occurred in other parts of the kingdom."

† The celebrated Rennell, in the 'Journal of the Asiatic Society,' gave a drawing of the changes of Indian rivers; and A. Tylor, in the 'Phil. Mag.' for 1853, attributed the movements of the channels to unequal rainfall.

takes place, of which I had a good example the last rains. The Markunda river 12 miles east of Umballa, where it is crossed by the Grand Trunk Road, had its deep channel too near the right

Fig. 2.—*Diagram Section of alluvial deposits.*



bank, which I was desirous of diverting by attaching brushwood to a chain. In the next flood what was in the evening the deepest channel was during the night raised about $3\frac{1}{2}$ feet, the deep channel being forced more towards the centre. When I came to dig into this sand bank, all thrown up in one flood, I found over an area of several hundred yards for the first 6 inches or so a dirty sand, for the next 3 inches a comparatively clean coarse sand, with a sharp line of demarcation above, and immediately below this a fine loamy reddish clay, some 15 inches thick, without any admixture of sand that I could observe, and underneath this again the same dirty fine sand that covered the surface. These intermittences all took place during the same flood of one night; so these different deposits were not the work of years, but of hours*. With such va-

* Where the Markunda is crossed by the Grand Trunk Road, at $\frac{1}{4}$ of a mile back from the river the ground is $5\frac{1}{2}$ feet below the river-banks on the east side; and a mile further on it is 13 feet below the bank, while on the west or Umballa side, $1\frac{1}{4}$ mile from the river, the land is $4\frac{1}{2}$ feet below the river.

This difference of fall on the two sides is owing to the line of road crossing the gravel-fall of the country, which is some $3\frac{1}{2}$ feet per mile in a rather oblique direction. The surface velocity with a 5-feet flood passing down was 6 feet a second. With high floods I found that the water held in suspension clay and sand as follows:—

		Clay.	Sand.			
Flood	9·9	=10·75	+47·5	=58·25	Per cent. by weight	4·83
,,	7·3	=13·37	+19·25	=32·62	,, ,,	2·74
,,	7·6	=13·00	+6·75	=19·75	,, ,,	1·65
,,	6·0	=11·87	+6·19	=18·06	,, ,,	1·50
,,	5·4	=11·65	+5·56	=17·21	,, ,,	1·43
					Mean	2·43

These results were taken by only one set of experiments; so no great dependance can be placed in them; but they show generally that the greater the flood the greater the proportion of sand to the clay, and that the transporting power increases at some quick ratio as the velocity increases. Professor Medlicot, I believe, made the proportion of silt in suspension in the flood-water of the Solani, which has a slope of some 5 feet in the mile, between 3 and 4 per cent.; and I made the Ratmao, which stream has a slope of 8 feet, to carry 5 per cent.; while the Puttri torrent, with a slope of 25 feet a mile, brought down 7 per cent. of silt by weight, though the flood at the time was about 3 feet only.

[Unless the cross section abuts on the slope of the stream it is impossible to calculate the velocity or the transporting force of the water.—A. T.]

riations therefore going on at the present day, it would be hopeless to attempt fixing any lapse of time for any individual deposit; but we must rather take it as a whole. But before going into this branch of the subject, it is proper here to state that at about a dozen miles below the hills, where these torrents have about as many feet of fall in the mile, or more, it is no uncommon thing to see clay boulders rolling down the beds of the streams; and these boulders are often studded with small stones stuck all round them. The floods being not of long duration, have not time to wear down and mix this stiff clay in the water; and the slope being great, and the stream rapid, these lumps of clay cut out of a stiff bank higher up the course, are thus rolled down; and as here shingle often occurs in the bed, the small stones stick to the clay and are carried down the stream. Having, it is hoped, given an idea of what is now going on, it may be as well for me to recapitulate some of the most important points at this stage before going further.

1st. It is probable that the total rainfall now is as it was 2000 years ago, but that it has undergone local changes, being less over the plains and more along the southern face of the Himalayas throughout the Punjab.

2nd. That the effect of this is that the rainfall has become less general both as to time and space; for if the air only parts with its moisture on reaching the hills, the chief rainfall can only be during the S.E. Monsoon. Hence the floods must be more intense than formerly, and consequently bring down proportionally larger quantities of sand than clay. From this we may safely conclude that there must be:—

1st. A lowering of the spring-levels.

2nd. A drying up of perennial streams.

3rd. A larger area covered with sand every year by the floods.

4th. More time to *blow back* the sand thus brought down by the floods over the surface of the country; or, in other words, the desert is encroaching rather than retrograding, from want of moisture.

If asked why is this? I should say that the only reason I can assign is centuries on centuries of bad and unsettled government, when every one cut down trees, but no man planted any. To meet this difficulty, we should by "Tuccavie advances" aid the villagers to store up water as formerly; and belts of trees some 200 yards broad should be planted every 5 miles and run parallel to the hills. The first line would probably begin some 10 miles south of Umballa, passing a little south of Loodiana, Umritsur, and Goojtanwalla, ending on the Jhelum a few miles north of Pind Dadun Khan. It may, and probably would, be many years before any observable change could take place in the climate; but I think there is every reason to suppose that if trees could be thus got to grow, what with the aid of irrigation-canals, and the minor irrigation-works above indicated, the intense heat of summer and cold in winter would be moderated, while the rainfall would become more general.

This general idea of what is now taking place in this part of India will, it is hoped, be found of assistance in explaining in what manner the plains of Northern India got deposited and attained their present state.

How the enormous mass of débris was formed which is now spread over the plains of India to as yet unknown depth I am not prepared to give a decided opinion; but, judging from what we see before us, I cannot help thinking that most of it must have undergone disintegration more than once. Possibly glacial action has aided in grinding up the older rocks; but such a force would leave this débris in angular masses, not in rounded boulders or as sand and clay. Most probably, however, a "pluvial period"* must have succeeded to wear down this mass into its present state, while this same power of water could carry forward this mass of matter and deposit it as we now find it. The foregoing statements, I hope, will explain how this matter comes to be deposited in alternate strata of sand and clay of irregular thickness, as the boring here at Umballa shows.

The level of the ground where this boring took place is 905 feet above the level of the sea; and as the tubes have been sunk to a depth of 455 feet, the bottom of the tubes is now 450 feet above the sea-level. For a distance of 385 feet, pipes of $9\frac{1}{2}$ inches diameter were sunk; and the remaining 70 feet was got by sinking 7-inch pipes inside them; thus the second set were relieved of side pressure for nearly five sixths of their length. The pressure exerted when the sinking of the first set of tubes was brought to a stand-still was equal to 64 tons, aided by taps from an iron ram; but as it was considered dangerous to apply any greater force, the second set of 7-inch pipes was forced down 70 feet further, when they also were brought to a stand-still by the breaking of the joint of the last pipe; but this was not before a pressure of 80 tons was exerted. The stoppage was owing to the lower pipe getting off the perpendicular; and it is supposed that this was in consequence of its having got among boulders.

The soil passed through, as will be seen by the appendix, has been alternate layers of clay and sand, sand and clay, of various thickness. Water was reached at 27 feet below the surface; and though all throughout the soil was water-bearing, yet in no case did it appear to be under pressure, except in one instance under a bed of kunkur; for not only did it not rise in the tubes, but latterly water had to be almost constantly poured down the tubes to prevent the sand rising in them. Some trials were made to test the supply at different depths; but the quantity was quite inadequate for any purpose; so as yet the result is *nil* as to reaching a good water-supply.

This want of upward pressure clearly goes to show that there cannot be any extended bed of clay as far as is yet reached, but that the deposits have all been in patches; for otherwise there must have been a rising of the water in the tubes, due to the difference of level between the points where the water was tapped and where it entered below the clay stratum on its upper or northern extremity. The deduction to be drawn from this appears to be that these strata

* Q. J. G. S. vol. xxiv. p. 120, 1868: Tylor, "Pluvial Period."

were not deposited in still water, but that they formed the beds and banks of streams. If there were any doubt on this point, I think it is completely set at rest by small stones and rounded clay boulders having been met with at from 250 to 295 feet below the surface. We see the very same in our torrents every day a few miles below the hills, where these streams are rapid; so it is only natural to conclude that these small stones and clay boulders were moved down the beds of rapid torrents in the same manner as they are at the present day.

With such facts it appears to me that, so far as has yet been reached, all the deposits were made by running streams along their course, and that none of these strata ever formed the bottom of lakes or inland seas.

It may also be stated here that possibly Central and Southern India may have been an island, the rocks at Delhi forming its northern extremity, the coast-line taking a south-westerly direction towards Bombay and Scinde, while the north-eastern shore would have followed very much the present course of the Jumna to where it joins the Ganges, and then very nearly the course of the Ganges to Rajmahal, which would have formed the most eastern portion of the island. Be this as it may, one thing appears very certain—that here at Umballa, at a very late date (speaking in a geological sense) the surface of the ground was only half the height above the sea that it is at present; and as far as we can judge from the gradually decreasing slope of the country from the hills to the sea, there has been no marked disturbance (with one exception) throughout the plains of Northern India, either along the valley of the Indus or that of the Ganges, but all the depressions which now exist throughout this large tract are due to denudation within a very late period of the world's history. This gradually decreasing slope is so uniform that, if the question were more fully gone into, I believe it would be found to approximate to a true parabola, as was first demonstrated by Mr. A. Tylor in certain cases*; and if this be true, it opens out an important field for investigation, not only to the geologist, as it would aid in determining dates, but to the hydraulic engineer, as it would throw much light on the vexed question of scour and deposit. Should this law be a correct one, it at once shows how the slope is dependent on the load carried by flowing water, and that we cannot rest contented with our empirical rules, which, for all we know to the contrary, may be quite opposed to the laws of nature.

Another very interesting fact to which I would here beg to draw particular attention is, that at a depth of 250 feet small stones and clay boulders, which indicate great velocities, were deposited on the softer soils underlying them. As these softer soils are abraded by velocities of a foot or even six inches a second, how comes it that these soils were not scoured away by probably ten times these velocities?

The conclusion I have come to for several years back is, that

* See Q. J. G. S. vol. xxv. p. 72, 1869.

whenever a river is in train (that is, when the water has got the proper load of solid matter due to its velocity) it loses all power of scour, be the velocity what it may.

This opens out a large subject for investigation of vital importance to hydraulic engineering; but as the object of this paper is to show what is at present going on, the better to enable us to form an idea of what occurred immediately before the present state of things, I will not discuss it. I have now to consider what has been the last great exception to which I have alluded. This is the upheaval of the Sewalik range, and the probable formation of the deep valleys through which our large rivers flow.

The accompanying section (fig. 3) shows by a dotted line, where the Sewaliks are crossed, what was probably the surface of the

Fig. 3.—*Diagram Section through the Sewaliks near Umballa.*

Vertical scale 600 feet to 1 inch. Horizontal scale 12 miles to 1 inch.

country prior to their upheaval. We have a remarkable corroboration of this curve-theory at Guneshpoor (B), which is a little over a mile south of the hills: a well has lately been sunk, and water was only reached at 120 feet below the surface of the dry or Babur tract; while where the dotted line is above the present surface is the tract known as the "Turai," where the spring-water rises to the surface. Now, as the upper surface of the high or Bhanghur level of the Doab is clay, if this deposit was at one time continuous, as shown by the dotted lines, it is evident that where the land was not disturbed by the upheaval of the Sewaliks, this bed of clay must exist.

This at once, I think, shows how we may have a small stream of water flowing down the bed of the torrent among the hills, but this water may be absorbed as soon as the line of disturbance is crossed; thus as soon as the water passes the point A it will disappear till it reaches the point C, when it will again appear at the surface; but at B water can be reached only at a considerable depth, which, in the present case, is 120 feet.

Having thus tried to explain how it is probable that the surface of the country did extend in the line C E D, the next subject to consider is how the depression C F G took place. This depression is simply a continuation of the valley of the Ganges, commonly called the "Khader," in contradistinction to "Bhanghur" or high-level plains of the Doab.

In a paper of mine read in 1869 before the British Association, to be found published in full in the Proceedings for that year, I have stated my views on this subject in connexion with roads and railways for Upper India; so, as this paper is rather voluminous, it is hardly necessary for me to dwell at great length on this branch of the subject.

Before this last convulsion of nature took place, it is probable that all the streams were broad and shallow rather than deep, and that they had much the same characteristics as those torrents we now find near the hills—that they were liable to, or perhaps always were in flood, bearing down large volumes of dirty water and depositing their surplus loads on either bank.

The reason why I am inclined to think these rivers were more or less in constant flood is, that, so far as the boring at Umballa has gone, there has been no indication of vegetable or animal life, but only of flowing water. It would however be presumptuous to say that neither animal nor vegetable life existed at this supposed pluvial period from one single boring, or even from several trials; but I only say that this is quite possible if it was a period of heavy rainfall, which most probably it was. Under such circumstances, with large volumes poured down the country from all along the southern face of the Himalayas, this filling-up process would rather lag behind in this neighbourhood, while the streams nearer Bengal would, relatively speaking, be nearer the sea; consequently, when a change did come, it would be found that there would be a long estuary or gulf extending far up above Rajmahal. At this time the general velocity would probably be reduced, and light soils chiefly carried down to form the surface, though this is not positively necessary; for boulders are often brought down along with clay held in suspension in the water: but be this as it may, we do find that the greater portion of the surface of the plains consists of lighter soils; and it is upon this that the fertility of the country depends. Sand we do find on the surface; but this I attribute more to wind and want of moisture than to aqueous action. Having thus got the surface in a prepared state for man to inhabit and cultivate the soil, the upheaval took place, raising a barrier to the numerous streams which then flowed over the plains, and only leaving openings or weak points at intervals, as at Hurdwar on the Ganges*, Tyzabad on the Jumna, Rooper on the Sutledj, and so with the Punjab rivers.

With the distance to the sea much shorter than at present, and the volume of water probably much greater, this water, with only a few channels to escape through at these gaps in the hills, must have rushed down with great violence, cutting and tearing before it deep channels through the plains, such as we now find the valleys of our great rivers, which are known by the name of Khader, in contradistinction to Bhangur, or high-level plains. With channels thus scooped out there must have been a cutting back; and the course of such minor streams as fall into the main rivers would be acted on similarly. Thus we find that this cutting back on the valleys of the Solani to near the foot of the hills must have been very great; for there the valley is even now 20 feet below the Bhangur, or high-level plain, and was probably much lower, while in width it could not have been less than two miles. When such was the state of things the velocity of the water must have been sufficient to carry large boulders from the foot of the hills to a considerable distance down the main rivers; and to me this explains why such boulders were found at a depth of 40 feet in the valley of the Jumna, when sinking the foundations of the Jumna railway bridge. If it is owing to this that in the Jumna valley at this point, which is quite as far from the hills as Umballa, large boulders were found at 835 feet above the sea, while as low down as 450 feet above the sea, at Umballa, only small stones were met with (the largest only measuring $5 \times 2\frac{1}{2}$ in.), what clearer proof than this is necessary that the beds of our large rivers are now being silted up rather than lowered?

This is a most important and satisfactory conclusion to the engineer; for here we have a deposit of some 40 feet of sand; and as the Delta † is rising also, every point between must be undergoing the same process, though perhaps not observable in one or even in several generations. To attempt to assign any specified time for such changes as we have been discussing, even for this last of all geological periods, would be in vain; but it probably required thousands of years to fill up the beds of these rivers after they were

* The opening through which the Ganges flows at Hurdwar is called "Beemgodah." Beem is a demigod of the Hindoos, who is said by them to have planted his foot at Hurdwar, and thus made a passage through the Sewaliks for the Ganges.

† [The Delta only rises in proportion as the mouths extend out to sea. If they did not extend and lengthen, the level of the Delta would fall as the mean level of the continent, being constantly diminished by the annual denudation due to the action of rain and rivers.—A. T.]

scooped out*. So also it would be premature to attempt to fix any date for the upheaval of the Sewaliks, and much more so to say when Delhi formed the most northern point of a large island, if ever the sea did reach north of where Delhi now is.

In fact this may be questioned, owing to the similarity of the soil and boulders brought up for the last 15 feet or so of the boring to that of the boulders and clay just below Kalka, where the Umballa and Kalka road crosses the line of the Sewaliks, which are very low at this point; and it was in the Sewalik range that Falconer and Cautley made their discoveries. If the strata immediately below the point now reached at Umballa are identical with the upper strata of the Sewaliks, fossil remains may be found; but up to the present time there have been no signs of animal or vegetable life†.

Should the strata be the same, we have now reached, at 450 feet above the sea at Umballa, strata which at 30 miles north of it are over 2000 feet above the sea; and if this curvilinear theory is correct, they were here deposited at a depth of about 1000 feet below their present level.

This will give a fall of over 15 feet a mile, or quite enough to roll along (in a moderately deep torrent) small boulders such as those met with near Umballa at 450 feet below the surface. If therefore large animals lived when the plains at Umballa were only half their present height above the sea, this might lead one to suppose that the sea did not reach as far north as Delhi, and possibly never did during the period now treated of.

This, however, is not the object of the paper to prove; but what it is wished to show is, that the plains of India were formed by mountain-streams in a similar manner to what we see at the present day—that though the deposits are irregular transversely, yet longitudinally the section is uniform, probably forming a regular curve. This curve Mr. Tylor proves to approximate to a true parabola in certain cases; and what I have observed of the torrents out here in India, and a few small experiments I have made, all go to support this view. To the geologist this would be a very interesting point to determine; but to the Hydraulic Engineer it is most important, as it would at once show that there is some relation between the load of solid matter flowing water can hold in suspension and the slope of the ground the water flows over—as, for example, that we cannot suddenly change the slope of an artificial river or canal without also modifying the load of solid matter to be carried. The second point of importance is the fact that the boring shows that we have heavy matter deposited over lighter matter, sand over soft clay, small stones over sand. This is also shown by the deposits in the Markunda (p. 190), where these were:—first, dirty fine sand; next, soft clay, and over this

* My estimate of the rise of the head of the delta of the Irrawaddy was 1 inch in 30 years. See 'Proceedings of the Royal Society of Edinburgh' for March 1857.

† Only on one occasion, at about 440 feet below the surface, were a few pump-fulls of a blackish putrid water brought up, giving off very much the same odour as the dirty bilge-water of a ship.

cleaner coarser sand, and last of all dirty fine sand again,—all deposited in the course of a few hours, and this in a river having a velocity of 6 feet a second and more. This to my mind proves that flowing water, once it has got its proper load, cannot cut the bed below. Therefore, to carry a constant load, there requires to be a constant velocity where the depth is uniform. The third and last is to show that the beds of our large rivers are rising rather than being lowered, however slow this process may be. This, to the engineer, is a most satisfactory conclusion to arrive at; for he knows he has only to guard against local scour and not a general depression of the beds of rivers passing through alluvial plains.

TABLE of Soil met with in boring the Artesian Well at Umballa.

Total depth.	Clay.	Sand.	Mixed.	Remarks.
4	4			
6	...	2	...	Firm sand.
9	3	...	...	Clayey soil.
11½	...	2½	...	Fine sand.
26½	15	...	...	Two beds; upper 3½ feet very stiff.
27	...	...	½	Stiff brown clay mixed with kunkur.
41	...	14	...	Fine sand; water-bearing at 32 feet.
50	9	...	...	Three beds; lower, 5½ feet, brown clay, and above this 2 feet of blue clay.
53½	...	3½		
56½	3			
67	...	10½		
69	2			
80	...	11		
85	5			
86½	...	1½		
122	35½	...	...	Very stiff brown clay.
124	...	...	2	Kunkur formation.
128	...	4		
137	...	...	9	Mixture of sand and clay.
139	...	2		
144	...	...	5	Mixture of sand and clay.
148	...	4		
150½	...	...	2½	Kunkur-bearing stratum.
154	...	3½		
166	12	...	...	Dark red clay.
174	...	8	...	Two beds, with 1 inch of shaly formation.
180	6			
181½	...	...	1½	Kunkur-bearing stratum; on getting through this, the water rose suddenly 40 feet, and in two hours to 70 feet.
183	...	1½		
184½	...	...	1½	Kunkur-bearing stratum.
196	...	11½	...	Two beds; lower, 6 feet, coarse sand. Pressure exerted on tubes 20 tons; temperature of water 78°.
196½	½			
199	...	2½		
202½	...	...	3½	Clay with kunkur.
211	...	8½		
212	...	...	1	Dark red clay with kunkur.
213	1			
214½	...	...	1½	Sand and clay with kunkur.
220½	...	...	6	Clay with kunkur, with black spots.

TABLE (*continued*).

Total depth.	Clay.	Sand.	Mixed.	Remarks.
223	2½	...	...	Clay with small particles of green sand. Pressure 20 tons.
234	...	11	...	Pressure 12 tons.
240	...	6	...	Coarse grey sand with 2 inches of stiff brown clay (probably a clay boulder).
240½	...	...	½	Brown clay with kunkur.
250	...	...	9½	Brown clayey sand.
266	16	...	...	Two beds; red clay mixed with kunkur.
266½	...	½	...	Fine soft sand.
276	9½	...	...	Two beds; lowest foot, stiff brown clay with
278½	...	2½		grey spots.
279	...	...	½	Coarse grey sand with kunkur.
286	...	7		
296	...	...	10	Two beds; coarse sand with clay boulders
297	1			and small stones.
299	...	...	2	Sand and clay.
302	...	3		
309	...	...	7	Clay with kunkur.
319	10	...	...	Sandy clay with mica.
325	6	...	...	Stiff brown clay.
327	2	...	...	Sandy clay (hard).
330	...	3	...	Soft dark brown sand.
335	...	...	5	Stiff brown clay with kunkur.
336	...	1	...	Dark grey sand.
338	2	...	...	Sandy clay.
349	...	11	...	Dark green sand.
362	...	13	...	Dark grey sand with kunkur.
363	1	...	...	Stiff red clay.
365	2	...	...	Yellow clay and sand.
376	...	11	...	Dark grey sand.
380	4	...	...	Dark clay.
381	...	1	...	Hard, dark-coloured.
387¾	6¾	...	...	Two beds; lower, 1¼ foot, dark red. Pressure exerted 64 tons, aided by hammering; 9¾-inch pipe injured and 7½-inch pipes substituted.
394	6¼	...	...	Red clay.
396	...	2	...	Dark grey sand.
399	...	...	3	Yellow coarse sand with scour.
403	...	...	4	Dark grey sand with large stones.
416	...	...	13	Very coarse gravel with boulders.
417	...	...	1	Very coarse grey sand with large stones.
420	3	...	...	Red clay.
424	...	...	4	Very coarse grey sand with stiff red clay and black kunkur.
431	7	...	...	Stiff red clay.
432	...	1	...	Dark running sand.
446	14	...	...	Red clay, very sandy.
448	...	2	...	Dark running sand.
449	1	...	...	Very stiff red clay.
451	2	...	...	Dark red loamy clay.
455	...	...	4	Dark running sand with clay boulders and kunkur.

TABLE (*continued*).

Summary.

Total depth of Clay	192	feet in	36 beds.
" " Sand	165½	" "	33 "
" " Sand and Clay	25½	" "	4 "
" " Kunkur-bearing beds	37	" "	14 ,
" " Boulder-bearing beds	35	" "	7 "
Total	455	feet in	94 beds.

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THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

February 21, 1872.

Frank N. Wardell, Esq., of Sandal House, Wakefield, Yorkshire, one of H.M. Inspectors of Coal Mines, and Mortimer Evans, Esq., C.E., of West Regent Street, Glasgow, and Skelmorlie Heights, Wemyss Bay, Ayrshire, were elected Fellows of the Society.

The following communication was read:—

Migrations *of the* Graptolites. By H. Alleyne Nicholson, M.D., D.Sc., M.A., Ph.D., F.R.S.E., F.G.S., Professor of Natural History and Botany in University College, Toronto.

Most geologists are now prepared to admit that the occurrence of the same species of marine animals in strata very widely removed from one another in point of distance may be accepted as a proof of "migration" having taken place. It does not matter, from this point of view, whether the deposits of the two areas are approximately of the same age, or whether they succeed one another in point of time—except that in the former instance we can hardly ever be sure which of the areas has been peopled from the other. It follows also from this view that strata containing exactly the same species of fossils, if very widely separated in point of distance, can never be *exactly* "contemporaneous." They may have been formed nearly at the same time, and they will belong to the same geological epoch; but the one must really succeed the other in point of time. It will be understood, of course, that this statement is only intended to apply to cases in which identical fossils are found at points so far removed from one another over the earth's surface, that we can never suppose them to have been connected by a single ocean the conditions of which were so uniform as to have allowed the spread of the same animals over its entire extent.

If we were thoroughly acquainted with the range of any given fossil vertically, and, at the same time, had all the necessary details as to what may be called its geographical distribution, we should then be able to lay down pretty accurately the lines along which it must have migrated when the conditions of its original area became unsuitable for its further existence therein. It is also possible that, in receding from its original area, we might find the species becoming modified in different directions, and ultimately giving rise to forms which we in our ignorance regard as well-marked varieties or, perhaps, as distinct species. In order, however, to arrive with any precision at such a conclusion, it would be necessary that we should know both the vertical and the lateral range of the fossil, and especially that we should know which of its several areas of occurrence is its original one. The vertical range of a fossil, or group of fossils, we may in many cases hope ultimately to learn with accuracy; and we may approximately determine its lateral range with sufficient exactness for practical purposes. It is, however, in most cases difficult or impossible to point to the original area in which a given fossil species appeared, and from which it spread, when we have several areas to choose from.

In the present state of our knowledge, any attempt to trace the migrations of any given species or groups of fossils must be more or less provisional and tentative. The present communication is an endeavour to arrange, as far as may be, such facts relating to the distribution of the Graptolites as enable us to sketch out the migrations effected by these singular organisms, from their rise in the Upper Cambrian period to their final disappearance at the close of the Upper Silurian period. In carrying out this endeavour, the genera *Dictyonema*, *Dendrograpsus*, *Callograpsus*, and *Ptilograpsus* will be left out of account, partly because they are only doubtfully referable to the Graptolitidæ, and partly because, in any case, their habit of existence must have been very different from that of the typical Graptolites.

A. Skiddaw Area.—Leaving the above genera out of consideration, the earliest Graptolites of Britain are found occupying an area in the north of England in which was deposited the dense mass of muddy sediments known as the Skiddaw Slates. I need not enter here into the age of these deposits beyond expressing my belief that they will ultimately be shown to belong to the Upper Cambrian period, and that they are certainly older than the Lower Llandeilo rocks of Wales. Though making their appearance here for the first time in Britain, the Graptolites are represented in the Skiddaw area by numerous genera and species, the greater number of which are peculiar. That the area was no small one is certain; and it can be shown to have extended at least as far as Lower Canada. This is proved by the large number of genera and species which are not only common to the Skiddaw Slates of the north of England and the Quebec group of Canada, but which are exclusively confined to these formations. The differences between the Graptolitic faunas of the Skiddaw and Quebec regions are not greater than can be well set down to imperfect observation or to the inevitable effect of difference of station, and certainly do not necessitate our supposing that the one region was peopled by migration from the other. Nor is the distance between the north of England and Canada so great as to compel our acceptance of this hypothesis; whilst the two regions are nearly in the same latitude, and are not separated by any impassable barriers. The case is different, however, with Australia, in which some of the peculiar genera of the Skiddaw and Quebec groups have been discovered. Here we are compelled to assume that we have a case of migration, though we have at present no data whereby to decide whether the course of the migration was from Canada to Australia (as is most probable), or *vice versâ*.

The following Table exhibits the species of Graptolites known to occur in the Skiddaw Slates, those which are common to the Quebec group being marked with an asterisk:—

*Dichograpsus octobrachiatus, *Hall.*	Peculiar to the Skiddaw group.
—— gracilis, *Nich.*	
—— annulatus, *Nich.*	
—— multiplex, *Nich.*	
—— reticulatus, *Nich.*	
*Loganograpsus Logani, *Hall.*	
*Tetragrapsus bryonoides, *Hall.*	
*—— Headi, *Hall.*	
*—— crucifer, *Hall.*	
*—— quadribrachiatus, *Hall.*	
*Phyllograpsus angustifolius, *Hall.*	
*—— typus, *Hall.*	
*—— Anna, *Hall.*	
Trigonograpsus lanceolatus, *Nich.*	
Didymograpsus affinis, *Nich.*	
*—— bifidus, *Hall.*	
—— fasciculatus, *Nich.*	
*—— nitidus, *Hall.*	
—— V-fractus, *Salt.*	
*Climacograpsus antennarius, *Hall.*	
Diplograpsus armatus, *Nich.*	
—— Hopkinsoni, *Nich.*	
*—— pristiniformis, *Hall.*	
Pleurograpsus (?) vagans, *Nich.*	
*Didymograpsus patulus, *Hall.*	Survive into the Lower Llandeilo.
—— geminus, *His.*	
Climacograpsus teretiusculus, *His.*	Survive into the Caradoc period, either in Britain or in America.
—— bicornis, *Hall.*	
Diplograpsus pristis, *His.*	
—— mucronatus, *Hall.*	
Didymograpsus serratulus, *Hall.*	

From the above Table it will be seen that the Skiddaw area was characterized by no less than five genera (viz. *Dichograpsus*, *Tetragrapsus*, *Phyllograpsus*, *Loganograpsus*, and *Trigonograpsus*, represented in all by fourteen species) which are exclusively confined to

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this horizon in Britain, and which died out at the close of the Skiddaw period. These genera, with one exception, likewise did not survive the close of the Quebec period in North America; and there is therefore reason to conclude that the termination of this period was effected in a manner which must have resulted in a large extinction of forms, only a few species, as we shall see, appearing to have accomplished a successful migration. In fact, out of a total of thirty-one species known in the Skiddaw Slates only seven seem to have survived to be preserved in later deposits; and the extinction seems to have been all but universal in the Canadian area.

Besides the above-mentioned genera, there appear in the Skiddaw area for the first time the genera *Didymograpsus*, *Climacograpsus*, and *Diplograpsus* (*Pleurograpsus* is only doubtfully represented, and may be left unconsidered). Of the eight species of *Didymograpsus* all but two are peculiar in Britain to this horizon; but *D. geminus* and *D. patulus* survive into the Lower Llandeilo. The migration of these two characteristic species appears to have taken place both southwards and eastwards from the Skiddaw area; for we find them both in the Lower Llandeilo rocks of Wales, and in the Lower Graptolitic Schists of Aher, in Scandinavia. A third *Didymograpsus*, viz. *D. serratulus*, Hall, appears to have survived the Skiddaw period and to have migrated in a westerly direction, since it is wanting in the later deposits of Britain but turns up after a prolonged lapse of time in rocks of Caradoc age (Utica Slate) in North America. This is the more noticeable, as the species is wanting in all the deposits older than the Caradoc in the United States.

Of the *Climacograpsi* one very characteristic species is peculiar to the Skiddaw Slates, as are three species of *Diplograpsus*. There remain *Climacograpsus teretiusculus*, His., *C. bicornis*, Hall, *Diplograpsus pristis*, His., and *D. mucronatus*, Hall, which survive into younger deposits. These species seem to have migrated from the area of the north of England at the close of the period of the Skiddaw Slates; and the course of the migration appears to have been in all cases the same. All these species, namely, appear in the Upper Llandeilo Rocks of Wales, the south of Scotland, and Ireland; so that the dispersal of these long-lived forms was general. It would not appear, however, that they extended their range very far beyond the British area in the earlier portion of the Lower Silurian period. Some of them reached the Scandinavian area, along with the two *Didymograpsi* above alluded to; but all these forms are wanting in the Silurian basin of Bohemia in the earlier phases of Barrande's "second fauna."

B. Llandeilo Areas of Wales and Scotland.—There are good grounds for the belief that the north of England was in the condition of dry land during the earlier portion of the Llandeilo period. At any rate, whether the close of the Skiddaw period was signalized by the upheaval of the Lake-district (as I believe), or whether the seas of the succeeding period were rendered unfit for life by intense igneous activity, it is certain that no deposits containing Graptolites are superimposed upon the Skiddaw Slates until we reach the later portion of the Bala period, at which time an immigration of Graptolites must have taken place from neighbouring seas. This being the case, the further course of the Graptolitic tree must be followed in other areas in which Lower and Upper Llandeilo deposits are developed. We must, then, change our ground, so far as Britain is concerned, from the north of England to Wales and Scotland.

In the Welsh area alone are Lower Llandeilo rocks developed; and we find in these *Didymograpsus geminus*, His., *D. patulus*, Hall, *Climacograpsus teretiusculus*, His., *C. bicornis*, Hall., *Diplograpsus mucronatus*, Hall, and probably *D. pristis*, His., all of which reached the Welsh area by migration from the Skiddaw area. With these, however, are *Graptolites sagittarius*, His., and *Dicranograpsus ramosus*, Hall, the former being only very doubtfully present. The genus *Dicranograpsus* is represented here for the first time; and, so far as we yet know, this may be regarded as the centre of dispersal of this afterwards widely distributed genus.

In the Upper Llandeilo area in Wales are found, of the species in the Lower Llandeilo, only *Climacograpsus teretiusculus*, *C. bicornis*, *Diplograpsus pristis*, and *Dicranograpsus ramosus*. All the other Lower Llandeilo forms appear to have died out in the Welsh area at this period. *Didymograpsus patulus* and *D. geminus*, especially, may be regarded as characteristic of the Lower Llandeilo horizon, since they never appear in any higher deposits in any other area. The only new form which appeared in Wales in this period is *Didymograpsus Murchisoni*, Beck. This beautiful species never seems to have succeeded in migrating out of the Welsh area; but there are reasons for believing that it is merely a very slightly modified descendant of the *Didymograpsus bifidus* of Hall, which abounded in the Skiddaw area, whence it probably migrated southwards.

The species of the Skiddaw area which migrated northwards into Scotland are *Climacograpsus teretiusculus*, *C. bicornis*, *Diplograpsus pristis*, and *D. mucronatus*; and all of these are represented in the Upper Llandeilo rocks of Dumfriesshire. With these old species, however, are now associated a large number of fresh forms, most of which are unknown in the corresponding rocks in Wales. As to the genera, we meet for the first time with *Rastrites*, *Cœnograpsus* (=*Helicograpsus*), *Retiolites*, and most probably *Pleurograpsus* and *Graptolites*. There are also many new species of the old genera *Climacograpsus*, *Diplograpsus*, and *Didymograpsus*. Of all these genera, *Rastrites*, *Cœnograpsus*, and most probably *Pleurograpsus* appear to have had their origin in the Dumfriesshire area, so far, at any rate, as can be judged from the fact that they occur in no older deposits in any other region. The two latter did not survive the close of the Upper Llandeilo period; but *Rastrites* not only passes on into later deposits, but becomes one of the most widely distributed genera of the Graptolitidæ. *Retiolites* is represented in the Skiddaw and Quebec groups by the allied genus *Trigonograpsus*; but the typical forms of this genus appear here for the first time. The genus survives, however, into far younger rocks, and becomes very widely distributed. The genera *Didymograpsus*, *Climacograpsus*, and *Diplograpsus*, as already indicated, were derived from the Skiddaw area, some of the species remaining unchanged. The genus *Didymograpsus* is represented here for the last time, so far as England and Scotland are concerned; whilst all the species are peculiar, and none of them seem to have been actual immigrants from the Skiddaw area. Some of them, however, as we shall see, migrated westwards, and reappear in strata of Caradoc age in North America. It should be noticed also that there is here a remarkable difference between the Scotch and Welsh areas, though both seem to have been stocked from the north of England. Four species, namely, of *Didymograpsus* appear in the Scotch area; and these are both widely diffused and abundantly represented by individuals. On the other hand, but one *Didymograpsus* (viz. *D. Murchisoni*) occurs in the Welsh Upper Llandeilo area; and this is extremely local and limited in its distribution. *Climacograpsus*, again, and *Diplograpsus*, whilst derived from the older Skiddaw area, have also representatives of their own; and both pass on into newer deposits. It may be noticed, however, in this place, that the only species of the Llandeilo Graptolites of Wales which would seem to have escaped extinction is *Climacograpsus teretiusculus*, His., which is also found in the Lower Llandovery—unless, indeed, the *Diplograpsus persculptus* of Carruthers, which also occurs in the Llandovery rocks, may be regarded as a modified descendant of *D. pristis*, His. With one or two doubtful exceptions, the great and varied genus *Graptolites* appears to have its commencement in the Upper Llandeilo area of the south of Scotland, where it is most abundantly represented as regards both specific types and individuals. It passes on, also, into much younger deposits.

Lastly, the genus *Dicranograpsus* would seem to have been introduced into the Upper Llandeilo area of the south of Scotland by migration from the Welsh area, where it is represented in the Lower Llandeilo. This genus dies out here, so far as England and Scotland are concerned; but, in company with many other forms, it would appear to have migrated westwards at the close of the Upper Llandeilo period, being found in rocks of Caradoc age in the United States.

The subjoined Table exhibits the genera and species of Graptolites of the Upper Llandeilo area of the south of Scotland, arranged in groups, according as they have been derived from preexisting areas, are peculiar (so far as known) to the Upper Llandeilo period, or pass onwards into higher deposits:—

Upper Llandeilo Graptolites of Scotland.

A. Genera.

Didymograpsus Climacograpsus Diplograpsus	Derived from the Skiddaw area.
Dicranograpsus	Derived from the Lower Llandeilo area of Wales.
Pleurograpsus	Probably peculiar to the Upper Llandeilo, but possibly commencing in the Skiddaw period.
Cænograpsus (=Helicograpsus) Rastrites Retiolites	Commence in the Upper Llandeilo, and pass onwards into higher deposits, either in Britain or in other areas.

B. Species.

Diplograpsus pristis, *His.*	Derived from the Skiddaw area.
Climacograpsus teretiusculus, *His.*	
—— bicornis, *Hall.*	
Dicranograpsus ramosus, *Hall.*	Derived from the Welsh Lower Llandeilo area.
Dicranograpsus formosus, *Hopk.*	Confined to the Upper Llandeilo.
—— Nicholsoni, *Hopk.*	
Didymograpsus anceps, *Nich.*	
Diplograpsus bimucronatus, *Nich.*	
—— Harknessii, *Nich.*	
—— insectiformis, *Nich.*	
—— cometa, *Gein.*	
—— acuminatus, *Nich.*	
Climacograpsus tuberculatus, *Nich.*	
—— innotatus, *Nich.*	
Pleurograpsus linearis, *Carr.*	
Rastrites capillaris, *Carr.*	
—— maximus, *Carr.*	
Didymograpsus sextans, *Hall.*	Confined to the Upper Llandeilo in Britain, but passing on into the Caradoc rocks of America.
—— flaccidus, *Hall.*	
—— divaricatus, *Hall.*	
Diplograpsus Whitfieldi, *Hall.*	
Cænograpsus (Helicograpsus) gracilis, *Hall.*	
Climacograpsus teretiusculus, *His.*	Pass on from the Upper Llandeilo into the Coniston Mudstones of the north of England (Caradoc).
Diplograpsus angustifolius, *Hall.*	
—— vesiculosus, *Nich.*	
—— pristis, *His.*	
—— palmeus, *Barr.*	
—— folium, *His.*	
—— tamariscus, *Nich.*	
Graptolites lobiferus, *M'Coy.*	
—— Sedgwickii, *Portl.*	
—— sagittarius, *His.*	
—— tenuis, *Portl.*	
—— Nilssoni, *Barr.*	
—— Clingani, *Carr.*	
Rastrites Linnæi, *Barr.*	
—— peregrinus, *Barr.*	
Retiolites perlatus, *Nich.*	

An analysis of the above Table shows us that out of a total of thirty-six species found in the Upper Llandeilo Shales of Dumfriesshire only four are derived from pre-existent areas, but these belong to three genera. Thirteen species are exclusively confined to this formation, and are not known to occur in younger deposits elsewhere, having seemingly died out at the close of the Upper Llandeilo period.

Five additional species are not known in Britain above this horizon, but evidently survived the close of this period, and were able to migrate, as they occur in the Caradoc rocks of North America. It should be noted here that this number might most probably be increased by some species of the genus *Graptolites*, which almost certainly occur in the Caradoc rocks of America. Owing, however, to Hall's disbelief in the existence of the genus *Graptolites* as defined by British palæontologists, this assertion cannot be made positively.

Sixteen species, or forty-five per cent., including the ancient species *Climacograpsus teretiusculus* and *Diplograpsus pristis*, survive the close of the Upper Llandeilo period in the British area. Eight of these hold their ground in their own area and, as we shall see, pass on into the younger deposits of the Gala group of the south of Scotland (Lapworth). The whole sixteen reappear also in the Coniston mudstones of the north of England (Caradoc). It is quite clear, however, that though eight species of a total of thirty-six, or twenty-two per cent., continued to exist in their original area in the south of Scotland, a great migration must have accompanied an almost equally great extinction of species, marking the close of the Upper Llandeilo period in the Scotch area. Seeing that so large a number of forms, as above mentioned, succeed in retaining their hold on their own area, it is difficult to assign any adequate cause for this migration ; but that such an exodus actually took place seems certain from the two following considerations :—In the first place, all the species of the total thirty-six inhabiting the Upper Llandeilo area of the south of Scotland, which did not actually die out, are found, to the number of sixteen, in the mudstones of the Coniston series of the north of England. Now these beds overlie the Bala or Coniston Limestone ; and the Upper Llandeilo rocks of Scotland underlie the same formation (Girvan Limestone). It seems certain, therefore, that the species of the Coniston mudstones were, to the above extent, derived from the Scotch area by migration ; and traces of such a migration are to be found in the Girvan Limestone itself. In the second place, six species of the Scotch area are found in strata of Caradoc age in Ireland. Five of these, and probably the sixth, are also found in rocks of about the same age in North America ; so that they reached Ireland *en route* for the American area, and the former country was merely the first halting-place in their migration.

C. Coniston Area of the North of England.—The above considerations lead me to the consideration of the second great Graptolitic period of the north of England, in which the mudstones of the Coniston series were deposited. Whatever may have been the sequence of phenomena at the close of the Skiddaw period, it is certain that the Skiddaw slates are overlain by a great mass of rocks in which no Graptolites are found. That this is really due to the absence of Graptolites from this area, and not to the general igneous activity shown by the nature of the rocks in question (Green Slates and Porphyries), is proved by the occurrence in the series of a dense mass of finely levigated dark-coloured shales, crowded with fossils, and perfectly suitable for the preservation of Graptolites, had such existed. The rocks to which I allude are the "Dufton Shales," which underlie the Coniston Limestone, and which contain no Graptolites. The Coniston Limestone itself, which corresponds with the Bala Limestone of Wales, is also wholly barren of Graptolites. Immediately above the Coniston Limestone, however, occurs a mass of dark mudstones, of variable but never great thickness, to which the name of "Graptolitic Mudstones" was applied by Professor Harkness and myself, owing to the extraordinary abundance in them of these organisms. It is perfectly clear, therefore, that the seas of the area of the Lake-district became abundantly stocked with Graptolites at a time immediately posterior to the deposition of the Coniston Limestone. The source whence these were mainly derived was unquestionably the south of Scotland, as shown by the following Table. It is to be noted also that the period of the Bala Limestone (Girvan Limestone) was not without Graptolites in the Scotch area; for at least one *Diplograpsus* and one species of *Graptolites* are known in this formation. The following Table shows the Graptolites of the Coniston mudstones, according as they are derived from the Scotch Llandeilo area, are peculiar, or pass upwards into younger deposits:—

Graptolites of the Coniston Mudstones.

Species	
Climacograpsus teretiusculus, *His.*	Derived from the Upper Llandeilo of the south of Scotland.
Diplograpsus angustifolius, *Hall.*	
—— vesiculosus, *Nich.*	
—— palmeus, *Barr.*	
—— folium, *His.*	
—— pristis, *His.*	
—— tamariscus, *Nich.*	
Rastrites Linnæi, *Barr.*	
—— peregrinus, *Barr.*	
Retiolites perlatus, *Nich.*	
Graptolites lobiferus, *M'Coy.*	
—— Nilssoni, *Barr.*	
—— Sedgwickii, *Portl.*	
—— sagittarius, *His.*	
—— tenuis, *Portl.*	
—— Clingani, *Carr.*	
Diplograpsus confertus, *Nich.*	Not found in the Upper Llandeilo. The first eight species are peculiar to the Coniston Mudstones. The last five species occur also in the Gala group of Scotland; and the last three of these pass on into the Upper Silurian.
—— Hughesi, *Nich.*	
—— sinuatus, *Nich.*	
—— putillus, *Hall.*	
Graptolites argenteus, *Nich.*	
—— bohemicus, *Barr.*	
—— fimbriatus, *Nich.*	
—— discretus, *Nich.*	
—— exiguus, *Nich.*	
—— turriculatus, *Barr.*	
—— colonus, *Barr.*	
—— priodon, *Bronn.*	
Retiolites Geinitzianus, *Barr.*	

It will be seen from the above Table that all the genera of the Graptolites of the Coniston mudstones of the north of England, and sixteen of the species, or more than fifty-five per cent., are identical with those occurring in the Upper Llandeilo rocks of Scotland. When we consider the relative age of these two deposits, it seems clear that the Coniston area was stocked by a migration from the older Scotch area. Not only is this the case, but it seems certain that the channel of migration between the two areas remained open during the whole of the period succeeding the deposition of the Bala Limestone. This is shown by the fact that, of thirteen species which occur in the Coniston mudstones but do not occur in the Upper Llandeilo, five species are likewise found in the Gala group of Scotland; and amongst these is the highly characteristic form, *Graptolites turriculatus*, Barr. This would go to prove that there was ultimately a migration in a reverse direction from the Coniston area into the Scotch area.

It may be admitted, then, that the fundamental elements of the Graptolitic fauna of the Coniston Mudstones were derived from Scotland; but this fauna nevertheless has its own peculiar species, whilst the absence of some of the Scotch forms is very remarkable. Thus no traces have ever been discovered in the Coniston mudstones of any species of the genera *Didymograpsus, Dicranograpsus, Cœnograpsus* (=*Helicograpsus*) and *Pleurograpsus,* so characteristic of the Upper Llandeilo area of the south of Scotland. On the other hand, there is a great development of the species of the genus *Graptolites* in the Coniston Mudstones, as compared with the Dumfriesshire Shales.

It may be as well to follow out here the further course of the Graptolites of the Coniston area. Immediately above the Coniston Mudstones comes a great series of rocks to which the name of "Coniston Flags"* was applied by Professor Sedgwick; and these in turn are surmounted by a still more extensive group termed the "Coniston Grits" by the same observer. The latter formation is certainly Upper Silurian, as has been shown by Mr. Hughes; and the former may very possibly also belong to the Upper Silurian period. Be this as it may, both formations contain Graptolites, often in considerable abundance as far as individuals are concerned; but there is here a wonderful diminution in the number of genera and species, as compared with the Coniston Mudstones. Thus the genera *Diplograpsus, Climacograpsus,* and *Rastrites,* abundantly represented in the Coniston Mudstones, are wanting altogether in the Coniston Flags and Grits, in which there remain only the genera *Graptolites* and *Retiolites.* One or two new forms of the genus *Graptolites* are present; but the commonest forms are *G. priodon, G. colonus,* and *Retiolites Geinitzianus,* all of which existed in the Coniston Mudstones.

It is clear, therefore, that the close of the period of the Coniston Mudstones was signalized in the north of England by the setting-in of conditions unfavourable to the existence of Graptolites. Of the twenty-nine species in the Mudstones, only three pass upwards into the immediately superjacent Flags, and the remaining twenty-six become, so far as this area is concerned, extinct. We shall see, however, that a considerable number of these were not absolutely extinguished, but that they migrated, a few northwards into Scotland, and the larger number in a south-east direction towards Bohemia.

D. Gala area of the South of Scotland.—Returning now to Scotland, I may endeavour to trace out the further dispersal of the Graptolites of the Upper Llandeilo area of Dumfriesshire. So far

* In my paper "On the Graptolites of the Coniston Flags" (Quart. Journ. Geol. Soc. vol. xxiv.), I included under the name of "Coniston Flags" both the Coniston Mudstones and the overlying Coniston Flags proper. The researches, however, of my friend Mr. T. McKenny Hughes, combined with my own investigations, have satisfied me that the two formations must be separated upon palæontological grounds, though no physical break has yet been shown to exist between them.

as Scotland itself is concerned, a considerable number of the Upper Llandeilo Graptolites continued to exist in their own area, though a still larger number became extinct. The remains of those which survived are found in a great series of rocks superior to the Dumfriesshire Shales and also to the Bala Limestone (Wrae Limestone), to which their discoverer, Mr. Charles Lapworth, applied the name of the "Gala Group." Regarding the Gala group, for the present, as a single series of deposits, the following Table exhibits the chief Graptolites which are known to occur in it.

Graptolites of the Gala Group.

Climacograpsus teretiusculus, *His.*	Derived from the Upper Llandeilo of the Scotch area.
Diplograpsus pristis, *His.*	
Rastrites Linnæi, *Barr.*	
Graptolites Sedgwickii, *Portl.*	
—— Nilssoni, *Barr.*	
—— lobiferus, *M'Coy.*	
—— sagittarius, *His.*	
Retiolites perlatus, *Nich.*	
Graptolites exiguus, *Nich.*	Derived from the Coniston Mudstones.
—— priodon, *Bronn.*	
—— colonus, *Barr.*	
—— turriculatus, *Barr.*	
Retiolites Geinitzianus, *Barr.*	

It appears from this list that the Gala group has yielded thirteen species of Graptolites, of which eight, or over sixty per cent., are identical with species of the preexistent Upper Llandeilo area. The diprionidian species of the genera *Climacograpsus* and *Diplograpsus* I give on the authority of Mr. Lapworth; but they have not come under my own notice, and they seem to be certainly absent from the higher part of the Gala Group. We have also to notice the absence in the Gala group, as in the Coniston Mudstones, of any representatives of the genera *Didymograpsus*, *Dicranograpsus*, *Cœnograpsus*, and *Pleurograpsus*. The remaining five species of the Graptolites of the Gala group are not survivors of the Upper Llandeilo fauna, but are all found in the Coniston Mudstones, and appear, therefore, to be importations from the Coniston area of the North of England.

The data at present in my possession do not enable me to speak positively as to the further career of the Graptolites of the Gala group. So far as is known to me, the only survivors of this period were *Graptolites colonus*, *G. priodon*, and *Retiolites Geinitzianus*, of which the two former occur in the Wenlock rocks of Kirkcudbrightshire, whilst the two last mentioned occur in the Ludlow rocks of the Pentland hills.

E. Hudson-River Area of North America.—The greatest migration of the Upper Llandeilo Graptolites of the south of Scotland appears to have taken a westerly course, and to have ultimately reached the United states, forming the well-known Graptolitic fauna described by Hall as occurring in the Hudson-River Shales and Utica Slates (Caradoc).

The grounds for this belief I will state immediately; but I may in the meanwhile introduce a Table of the Graptolites of these formations.

Graptolites of the Hudson-River Shales and Utica Slates.

Diplograpsus pristis, *His.*	Derived from the Upper Llandeilo of the south of Scotland.
—— mucronatus, *Hall.*	
—— Whitfieldi, *Hall.*	
—— angustifolius, *Hall.*	
Climacograpsus bicornis, *Hall.*	
—— teretiusculus, *His.*	
Dicranograpsus ramosus, *Hall.*	
Didymograpsus sextans, *Hall.*	
—— divaricatus, *Hall.*	
—— flaccidus, *Hall.*	
Cænograpsus (Helicograpsus) gracilis, *Hall.*	
Graptolites sagittarius, *His.*	
—— tenuis, *Portl.* (?)	
Didymograpsus serratulus, *Hall.*	Derived from the Skiddaw area?
Diplograpsus putillus, *Hall.*	Not occurring in the Upper Llandeilo, and all, except the first, peculiar to this formation.
—— quadrimucronatus, *Hall.*	
Climacograpsus typicalis, *Hall.*	
Dicranograpsus furcatus, *Hall.*	
Rastrites Barrandi, *Hall.*	
Retiograpsus eucharis, *Hall.*	
—— Geinitzianus, *Hall.*	
Dichograpsus (?) multifasciatus, *Hall.*	

It appears from this list that, excluding some doubtful forms, there are twenty-two species of Graptolites known from the Hudson-River group and Utica Slates. The grounds upon which we may assume these to have been mainly introduced into America by migration from Scotland are as follows:—1. Of the abundant types of Graptolites in the older formation of the Quebec group of Canada not one single species occurs in the Hudson-River group; whilst there is preserved but one of the peculiar genera of the former, and that is represented by but one species (*Dichograpsus? multifasciatus*). It is clear, then, that a great extinction of Graptolites took place at at the close of the Quebec period; and we cannot look to the rocks of this group as the source of the Graptolites of the Hudson-River area. 2. Of the total of twenty-two species of Graptolites known from the Hudson-River group, no less than thirteen, or nearly sixty per cent., are *specifically* identical with forms which occur in older deposits of the Upper Llandeilo area of the south of Scotland. 3. At least seven of these thirteen species have been detected by Mr. Baily in strata of Caradoc age in Ireland; and we may well believe that Ireland constituted an intermediate station in the migration of these species from Scotland westwards.

It should be noticed also that this great westward migration of the Upper Llandeilo Graptolites of the south of Scotland led to the preservation into the Caradoc period of the genera *Didymograpsus*, *Dicranograpsus*, and *Cænograpsus*. These three genera, namely, seem to have failed to make their way southwards; they are wanting in the Coniston Mudstones, whilst they died out in their own area, and are not to be found in the Gala group; they are to be found, however, in the Caradoc strata of Ireland, and in the Hudson-River group of North America.

F. Saxon and Bohemian Areas.—I have now endeavoured to show that two great migrations of Graptolites took place from the area of the south of Scotland at the close of the Upper Llandeilo period—one westward through Ireland to America, the other southward into the north of England. I shall now try to show that a third great migration took place at the same time from the same area, in a south-east direction, into the Silurian seas of Saxony and Bohemia.

The Graptolitiferous rocks of the "Grauwackenformation" of Saxony are believed by Geinitz to form the summit of the Lower Silurian series; so that they would correspond pretty closely with the upper portion of the Caradoc series. That the Graptolites of this series were derived from the British area is shown almost conclusively by the subjoined list of Saxon species identical with British forms:—

Saxon Graptolites derived from Britain.

Diplograpsus pristis, *His.*	Species derived from the Upper Llandeilo of the south of Scotland.
—— palmeus, *Barr.*	
—— folium, *His.*	
Climacograpsus teretiusculus, *His.*	
Graptolites sagittarius, *His.*	
—— Nilssoni, *Barr.*	
—— tenuis, *Portl.*	
—— lobiferus, *McCoy.*	
—— Sedgwickii, *Portl.*	
Rastrites peregrinus, *Barr.*	
Graptolites priodon, *Bronn.*	Species derived from the Coniston Mudstones.
—— colonus, *Barr.*	

All these species occur in the mudstones of the Coniston series; but it is tolerably clear that they were not derived from this source, but from an area like the Upper Llandeilo of the south of Scotland, in the seas of which the genus *Didymograpsus* was represented. Two *Didymograpsi,* namely, occur in the Silurians of Saxony; and one of them, at any rate, seems to be identical with a Scotch species. It is also clear that the channel of communication between the British and Saxon areas remained open for a long period, since the Silurian rocks of Saxony contain *Graptolites priodon* and *G. colonus,* both of which are wanting in the Upper Llandeilos of Scotland, but appear in the later deposits of the Gala group and in the mudstones of the Coniston series. It is probable, therefore, that more than one migration of Graptolites took place at different periods from the British to the Saxon area.

Almost all that has just been said about Saxony would apply to the case of the Bohemian area; but I must not omit to notice that M. Barrande has already recognized the British derivation of the Bohemian Graptolites (Défense des Colonies, 1870). We may therefore regard the stocking of the Saxon area with Graptolites as being merely an early stage in a steady easterly migration of these organisms from British seas towards the close of the Lower Silurian period.

M. Barrande recognizes two chief Graptolitic zones in the Silurian series of Bohemia, viz. Etage D, at the summit of the Lower Silurian series, and Etage E, at the base of the Upper Silurian series. Palæontologically the two groups present little difference so far as the Graptolites alone are concerned; and I may therefore treat them from the present point of view as being inseparable, or rather I may confine my remarks altogether to Etage E. The following Table shows the number of species common to Etage E and the mudstones of the Coniston series.

Bohemian Graptolites derived from Britain.

Climacograpsus teretiusculus, *His.*	Species in Barrande's Etage E derived from the Coniston Mudstones of the north of England.
Diplograpsus folium, *His.*	
—— palmeus, *His.*	
Graptolites bohemicus, *Barr.*	
—— colonus, *Barr.*	
—— priodon, *Barr.*	
—— lobiferus, *McCoy.*	
—— Sedgwickii, *Portl.*	
—— sagittarius, *His.*	
—— Nilssoni, *Barr.*	
—— turriculatus, *Barr.*	
Rastrites Linnæi, *Barr.*	
—— peregrinus, *Barr.*	
Retiolites Geinitzianus, *Barr.*	

From this Table it will be seen that no less than fourteen species of Graptolites known in Etage E, at the base of the Upper Silurian series of Bohemia, are identical with species which lived in the older area of the Coniston Mudstones of the north of England. There need therefore be little hesitation in accepting Barrande's view that the Graptolites of the Bohemian area were derived by migration from the British area. Many of the species are common to the Lower Llandeilos of the south of Scotland; but that the migration was from the Coniston rather than the Scotch area is shown by the total absence in Bohemia of the genus *Didymograpsus*. The Bohemian area, therefore, must have been stocked by a migration which took place at the end of the Caradoc period, rather than towards its commencement, the Saxon area being chiefly peopled at the latter epoch.

The close and numerous points of resemblance between the Graptolites of Barrande's Etage E and the mudstones of the Coniston series, formerly led me to think that Etage E should be removed to the summit of the Lower Silurian series (Quart. Journ. Geol. Soc. vol. xxiv.). This opinion, however, was formed hastily, and without a due consideration of the facts bearing upon the distribution of the Graptolites; and I must now fully admit that M. Barrande's explanation of the facts is a more satisfactory solution of the difficulty, whilst it harmonizes entirely with the other facts which I have put together on this subject. It appears, then, that the diprionidian genera *Climacograpsus* and *Diplograpsus* are not, as formerly thought, exclusively confined to the Lower Silurian series, but that in Bohemia, at any rate, they extend their range into the Upper Silurians. These two genera, however, have not been shown to transcend in other localities the limits of the Lower Silurian series; whilst their place may be taken, as palæontological guides, by the genera *Didymograpsus* and *Dicranograpsus*, neither of which has as yet been detected in any Upper Silurian deposit.

Discussion.

Mr. Etheridge commented on the importance of Dr. Nicholson's paper, and on the difficulties attending the study of the Graptolitidæ. The migration of these organisms appeared to him to be very difficult to establish, especially in connexion with their extension both eastwards and westwards.

Mr. Hughes believed that if we could discover the original of any species, we should see a small variety appearing among a number of forms not very different from it, and from which it had been derived; but when the variety had prevailed, so as to be the dominant form, we were far on in the history of the species; that it was a great assumption to fix upon any bed we now know as representing the original source of any group; that we know too little about the chronological order of the geological divisions referred to to reason with any safety on the migration of Graptolites from one area to another—that the term *Lower* Llandeilo, for instance, was very unsatisfactory as used in the paper; there was nothing lower than the Llandeilo Flags at Llandeilo; and where older beds occurred in Scotland and elsewhere, it was not at all clear that the equivalent of the Llandeilo Flags was present at all. He differed also altogether from the author as to the position of the Dufton Shales, and criticised the views of the author as to the range of some species. He thought that M. Barrande's theory of colonies was borne out by the study of the Graptolites, but that we had not sufficient data to speculate as to the areas in which they made their first appearance, or the order of their geographical distribution.

Prof. Duncan observed that, at the present time, there was among other forms quite as great a range of species as that of the Graptolites pointed out by the author. Having looked through all the drawings of Graptolites that he could meet with, he had found none whatever that were accurate; and he had moreover never in any specimens discovered such cups or *calices* between the serrations as were always attributed to these organisms. From all he had seen he was led to the conclusion that the projections on the Graptolites bore the same relation to the central stem as those of some of the Actinozoa. These latter also, like the Graptolites, seemed to prefer a muddy sea. Professor Duncan also suggested that the Graptolites were really the remains of the filiform polypiferous parts of floating Hydrozoa.

Prof. Morris regarded the paper as mainly suggestive. It was on all hands agreed that there were in Britain two principal zones in which graptolitic life was most abundant; and the same held good in America. Both these seemed to be homotaxially related. M. Barrande had long since pointed out the probable migration of many of the Bohemian species from the British area; and there could be no doubt of there being many species common to Europe, America, and Australia. This afforded strong evidence in favour of some such theory as that of migration. He cautioned observers to take careful notice of the manner in which Graptolites are presented in their matrix; for, when seen from three different points of view, they exhibited such differences that three species might be made from one form of organism.

Mr. Gwyn Jeffreys mentioned the wide distribution of marine Hydrozoa by means of winds and currents, as illustrative of the history of Graptolites, the dispersion of which might have arisen from similar causes, and not from migration.

Mr. Prestwich commented on the uncertainty of our knowledge with regard to Graptolites, and consequently regarded speculation on the subject of their migration as premature. He instanced *Cardita planicostata*, which was formerly regarded as having originated in the Paris basin and come thence into England, but which had since been found in far earlier beds in Britain, so that the presumed course of its migration has been reversed.

Mr. Hicks remarked that the rocks referred by the author to the Upper Cambrian were in reality the lowest of the Silurian series, and that the Graptolitidæ were exclusively a Silurian family.

Mr. Hopkinson also made some remarks both on the distinction of different species of Graptolites and on their distribution. He regarded the Quebec area as that in which these forms had originated.

Prof. Ramsay commented on the great want of accord among those who had studied Graptolites, not only with regard to their structure, but to their distribution in different horizons. He thought that the suggestion of the author, as to modification of form during migration having taken place, seemed to throw some light on the subject. He could not regard two districts now only separated by the Solway Firth as constituting two geographical areas so distinct that the occurrence of the same species in both could with propriety be held to be due to migration. The phenomena in the other cases seemed to him quite as much in accordance with distribution from some common centre as with migration along any line connecting two spots where Graptolites are now found. He thought that the recurrence of some forms on different horizons in Cumberland was to be accounted for by the fact that the rocks which intervened between the Skiddaw Slates and the shales immediately above the Coniston Limestone were subaërial volcanic beds, on which, after submergence, newer muddy shales had been deposited.

March 6, 1872.

John Charles Melliss, Esq., C.E., 90 Richmond Road, Westbourne Park, W., and Thomas Mellard Reade, Esq., C.E., of Heath House, Blundellsands, Liverpool, were elected Fellows of the Society.

The following communications were read:—

1. *On* Prognathodus Güntheri, Egerton, *a new* Genus *of* Fossil Fish *from the* Lias *of* Lyme Regis. By Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S.

[Plate VIII.]

Representatives of the Chimæroid family have hitherto been of very rare occurrence in the Lias. In 1847, when I communicated a paper to the Geological Society "On the Nomenclature of the Fossil Chimæroid Fishes," only one specimen was known, *Ischyodus Johnsoni*, described by Professor Agassiz in the third volume of the 'Poissons Fossiles,' p. 344, and figured on pl. 40 c. fig. 22. Although included in the tabular arrangement appended to that paper, I nevertheless entertained much doubt as to the real position of this species; it differed so much from the other members of the family in the characters of the premaxillary teeth.

In the Chimæroid genera, both recent and extinct, these are subtriangular, composed of parallel columns of coarse dentinal matter arising from a basal pulp-cavity and lodged longitudinally in cavities of a plate of softer material, so that the unequal wear of the two substances serves to maintain notched cutting-edges at the extremities. These multiple denticles are coated externally and internally with a superficial layer of a harder material resembling ganoine. The premaxillary tooth of the Liassic specimen differs remarkably in these particulars. Although imperfect, it measures one inch and a half in length, and has a uniform breadth of half an inch. So far from being subtriangular, it resembles somewhat the incisor tooth of a gigantic Rodent, except that the inner facies is concave, and consequently the transverse section is crescentic. The profile of the tooth describes a gentle curve from the base to the extremity. The interior is composed of a homogeneous tissue of coarse tubular dentine, enveloped all round with a casing of harder material. The wearing away of these substances produces a sharp chisel-shaped edge without notches or serrations. The maxillary plate is also unlike that of any of the fossil Chimæroids, having the triturating area composed of one broad convex layer of dentine, instead of three molar surfaces as in *Edaphodon* and *Chimæra*, or four, as in *Ischyodus*. In this respect it has more resemblance to *Callorhynchus*. The mandibular plates exhibit the same peculiarity of having the triturating surfaces continuous instead of being interrupted by bony septa (as is the case in the other members of this family). All these teeth have those exposed surfaces which are not subject to attrition in mastication invested with a thin layer of ganoine, corresponding, in this respect, with the typical Chimæroids.

After waiting patiently more than twenty years for further materials to elucidate this aberrant form, a specimen has come into my hands, through the good offices of Lord Enniskillen and Dr. Günther, which throws some light upon this subject. The specimen has been for some time in the possession of a man named More, at Lyme Regis, who, fancying he had found a fossil Bat, set so extravagant a price upon it that he had the satisfaction of retaining it in his possession longer, perhaps, than suited his pocket. At length, however, Dr. Günther succeeded in purchasing it at a more reasonable figure, and consigned it to Lord Enniskillen, who has entrusted it to me to describe.

The first feature that arrests attention is the peculiar form of the premaxillary tooth, identical with that of *Ischyodus Johnsoni*, but having the outer surface displayed instead of the interior (Pl. VIII. *p*). We learn from this that this surface was striated longitudinally, and that one side of the tooth was flattened for the apposition of the fellow incisor. Extending at right angles on either side of the median line, two plates of bone are seen occupying the position of, and probably representing the maxillary teeth, or, perhaps, the bone supporting them (Pl. VIII. *m*, *m*). The base of the premaxillary tooth is lodged in a shallow socket at the median line; and a similar socket is seen for the reception of the corresponding tooth of the right side. The maxillaries are each one inch and a half in length; but, being imbedded in the matrix, the triturating surface is not discernible. Beneath, and in advance of the right maxilla, the mandible of the same side is preserved with the inner surface exposed. The principal tooth (Pl. VIII. 1) resembles in form the mandibular plate of *Ischyodus*; but the two ridges traversing obliquely the grinding-surface are more prominent, and are coarsely notched. So far, this specimen might be considered as belonging to the Chimæroid family—perhaps an aberrant form of *Ischyodus*. Fortunately, however, the anterior parts of the lower jaw are preserved in their natural position, and represent a dental apparatus unlike any thing hitherto known, except in some of the Cochliodont genera of the Mountain Limestone. Immediately in front of the right mandible, and attached to what (in the absence of ocular demonstration to the contrary) might have been termed its symphysial facet, a tritoral tooth occurs not unlike one of the genus *Helodus* (Pl. VIII. 2). It is equilateral and triangular in form, and measures half an inch on each side of the triangle. The grinding-surface is uneven; and the tubercular prominences with which it is studded show signs of attrition. Preceding this there is another tritor, of smaller dimensions and more elongated form, having the tubercles arranged in oblique rows; these also bear evidence of wear and tear (Pl. VIII. 3). Alongside of these teeth the corresponding pair of the other side are preserved *in situ*.

The dental formula here disclosed is unlike any thing we know among the recent Plagiostomatous fishes. If we turn to extinct forms, we find that the mandibular teeth agree in number with those of *Cochliodus*; but as the maxillary apparatus of this genus is unknown, no comparison can be instituted in this region of the mouth. The number of its component teeth corresponds with the maxillary armature of the Chimæroids. On referring to structural analogies, we find that the teeth in this fossil follow rather the Chimæroid than the Cochliodont type, inasmuch as in the latter the dentary plates were horizontal, rolling round and embracing, as it were, the alveolar margin of the lower jaw; whereas in the former they are vertical, and have the dentary portions supported by an osseous matrix, enveloped both without and within with a coat of ganoine on those parts not subservient to molendular attrition. The occurrence of these two pairs of anterior molars in the lower jaw accords with the unusual elongation of the premaxillary or incisor teeth. Were the mandibular plates united at the symphysis (as in all the typical Chimæroids), the premaxillaries would have overlapped them, and, having no opposing whetstone to work upon, would have continued growing from the basal pulp-cavity (like the distorted incisor of a Rodent) until they would have been an incumbrance to the fish rather than auxiliaries in providing for its sustenance; but, by the anterior extension of the mandibular dental apparatus, provision is made for the opposition of the upper and lower teeth, by which a permanent prehensile apparatus is secured for seizing and tearing the prey preliminary to the mastication which it would subsequently undergo between the crushing surfaces of the hinder molar teeth.

Besides the dental machinery which has been described, the specimen comprises other features no less singular. Attached to the upper edge of the maxillary plates, and extending three inches on either side of the mesial frontal line, there is seen a broad horizontal plate with a sinuous outline, which suggested to the finder the semblance of the wings of a Bat. It appears to be composed of a cartilaginous material, without any trace of osseous structure, and with no sutures or other demarcations on its surface. The lateral extremities are rounded; and that on the right side is overlapped by a plate of a harder material, studded over with a tubercular pattern very similar to that common on the cranial bones of some of the secondary Ganoid Fishes. This plate is semielliptic, having the base, which is directed forwards, concave, and the outer curve armed with two strong dermal spines. The inner curve has the appearance of having been united by a squamosal suture to an adjoining plate; and this leads to the supposition that the cranial cartilage was entirely cased by similar plates, as in the recent *Acipenser*. It is also highly probable that the orbit was situated beneath the concavity in what may therefore be considered the supraorbital plate, protected by the spines projecting from the margin of the plate (Pl. VIII. *o*). On either side of the frontal mesial line, and superimposed upon the cartilage, is a cylindrical osselet one inch in length. These bones have their anterior extremities coincident with the bases of the premaxillary teeth, affording to them support, and perhaps attachment for muscles connected with the masticatory function. Dr. Günther informs me that he has found a pair of nasal cartilages in a similar position in the recent *Chimæra monstrosa*. Both these and the cranial plate must be composed of a more indestructible material than ordinary cartilage, which is rarely found in the fossil state.

Taking all the characters of this singular specimen into consideration, it will, I think, be conceded that this Fish is a novelty in palæichthyology of no ordinary interest. The form of the head, extended in the horizontal instead of the vertical plane, suggests the strange appearance of a *Zygæna*, but covered with hard plates like a Sturgeon. The maxillary teeth most resemble those of *Callorhynchus*, the mandibular apparatus that of *Cochliodus* or *Deltoptychius*, while the premaxillaries are unlike those of any genus either recent or fossil. In proposing for it the generic title *Prognathodus*, I desire to express one of its most remarkable peculiarities—and in the specific appellation to recognize the obligation I am under to Dr. Günther, not only for securing this valuable addition to ichthyology, but for his invariable kindness in assisting me with his unrivalled ichthyological knowledge on this and other occasions.

The species alluded to as *Ischyodus Johnsoni* must be associated with *Prognathodus* in consequence of the identical characters of the premaxillary teeth; but, as it differs specifically from *P. Güntheri*, it will retain its specific name.

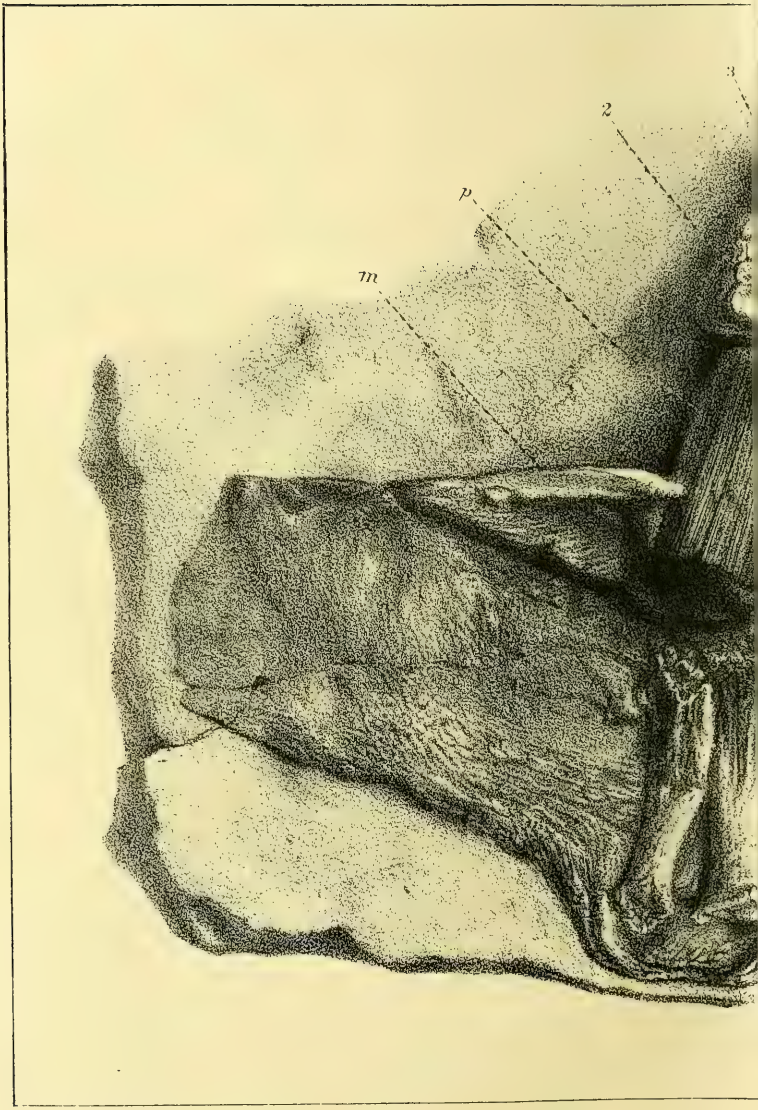
EXPLANATION OF PLATE VIII.

Head of *Prognathodus Güntheri*, Egerton, nat. size: *m*, maxillary teeth; *p*, premaxillary tooth; *o*, cranial plate?; 1, 2, 3, mandibular teeth.

Discussion.

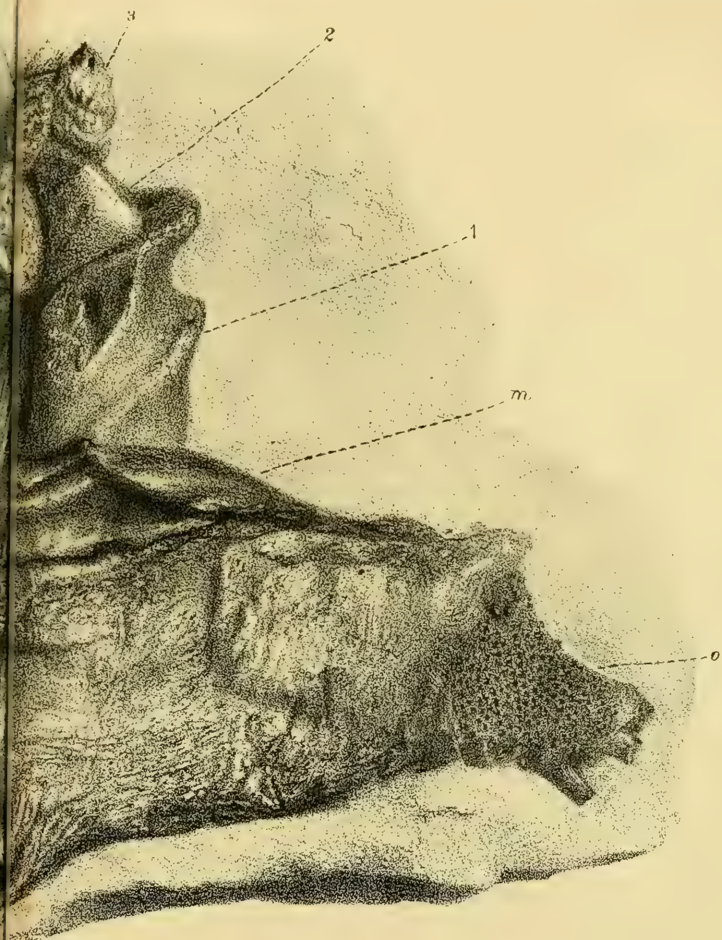
Dr. Günther pointed out the interest attaching to the dentition of this fossil fish as being an additional evidence in favour of the connexion between the Ganoid and Chimæroid forms. The existence of three teeth instead of one on each side of the jaw, as in *Ceratodus* and others, presented in it a generic character; but the type was still the same. On one point he slightly differed from the view of the author; and that was as to the application of the terms maxillary and premaxillary to the teeth. He thought the former belonged rather to the pterygo-palatine arch, and that the teeth in the front of the jaw should be regarded as vomerine. He illustrated this by reference to the jaws and dentition of Sharks, Chimæroids, and certain Ganoids. In these the teeth, instead of being connected with the maxillary and premaxillary bones, were, in fact, connected with the pterygo-palatine arch. He considered that this furnished additional grounds for including all three forms in one subclass.

Mr. Etheridge made some observations as to the horizon in the Lias on which these fossil fishes occurred. He believed that nine out of ten of the Lower Lias species came out of the upper part of the *Bucklandi* limestone series. At the base of the cliff at Pinhay, Lyme Regis, are the Black Shales of the Rhætic beds; above them is the White Lias, in which there are no fish, though they occur on the same horizon elsewhere; above these a series of shales with *Ostrea*, and above these again shales and limestones with *Lima gigantea* and *Ammonites Bucklandi*, the whole forming the *Bucklandi* series. The fish-beds (some 8 or 10 feet thick) contain about eighty species of fishes. Above this horizon fish are almost unknown in the Lias of Dorsetshire. At Barrow the fish also occur in the *Bucklandi* series, though somewhat lower down. In other cases fish-remains seem also to be restricted to certain horizons; and the exact position of such remains as these was, in his opinion, an important feature in determining their distribution both in time and space.



J.Dinkel.

PROGNATHODU



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PROGNATHODUS GUNTHERI. *Egerton*

Sir P. Egerton corroborated Mr. Etheridge's views as to the localization of species of fish, and agreed with him as to the importance of recording the exact position of all such fossils.

Prof. Ramsay was gratified to find that these connecting links between different genera were being discovered. They seemed to him to foreshadow the time when the word genus would become extinct; while at the same time the careful researches of the author and others tended more and more to establish the truth of the great theory of evolution.

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2. *On* Two Specimens *of* Ischyodus *from the* Lias *of* Lyme Regis. By Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S.

[This paper is withdrawn by permission of the Council.]

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3. *How the* Parallel Roads *of* Glen Roy *were formed.* By James Nicol, Esq., F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen.

[Abridged.]

In a paper on the "Origin of the Parallel Roads of Glen Roy," read before the Society and published in the Quarterly Journal for August 1869, I described some physical facts which appeared to me to place their marine origin beyond doubt. So far as I am aware, no attempt has been made to answer that argument.

But I have been asked "to explain the extraordinary coincidence of the sea-level with five (four) successive cols." It has been further asked how, if the same sea filled Glen Roy and Glen Gloy, it formed a road in the latter and none in the former glen; why are the lines of partial occurrence even in this region—the highest limited to Glen Gloy, the second and third almost to Glen Roy, whilst the fourth extends round both Glen Roy and Glen Spean? If all the time the same sea filled all these glens, and was liable to the same oscillations of level, why has it formed roads in one or two of them only, not in all? Why are not the second and third roads as well seen in Glen Spean as in Glen Roy, and the Glen-Gloy line not in one only but in all the three? These questions plainly need to be answered; and the answer, in my opinion, forms the key to the whole of the phenomena.

Facts stated in my former paper proved that, shortly before the formation of the roads, this part of Scotland was submerged in the ocean, which laid down the detritus in which they are cut. When the land began to rise, first the summits of the highest hills would appear as detached shoals and islands, on which ice-borne boulders have been deposited. Then more considerable masses of land would emerge, separated by narrow marine channels or straits. Glens Gloy, Roy, and Spean were at one time such channels, opening with wide funnel-like mouths to the west, and narrowing towards the east. Then, as now, a strong tidal current from the west—aided also, we may believe, by the Gulf-stream—would set into these channels, and tend to raise the water on the west side of the islands higher than on the east. This is the case at present, when the mean level of the sea is some four feet higher at the west than at the east end of the Caledonian Canal. The amount of elevation, however, would be modified as the currents could flow with more or less freedom through the open straits to the east; and were these outlets wholly closed, the water, no longer able to flow away to the east, would accumulate on the other side of the barrier, and a considerable rise in the sea-level in the western bays would necessarily be established.

Let us now look at what would happen during the slow, regular rise of the land. So long as the channels were open throughout, as the land rose the sea would fall on the shore, lower and lower, we may say, at each successive tide, and spread the detritus in a uniform layer over the declivities. When, however, the bottom of one of the straits rose above the surface at low water, a new state of things would commence. The tidal currents would be checked in their eastward flow, and the sea-level in the western bay would begin to rise, and continue rising till the strait was wholly closed even at high tide. During the intermediate period, though the land was rising, the western sea was not falling, but was *virtually* stationary. When at length the rise in the land entirely shut the strait, then (the full effect of the interposed barrier being attained) the sea in the western bays would anew begin to fall uniformly and regularly as the land rose. We have thus an interval more or less prolonged of stationary sea-level interposed between two periods of regular uniform sea-depression. During this interval the sea would act for a long time continuously on one line of land, and thus make a deeper indentation into the detritus. This indentation is one of the present roads; it marks the period during which the col rose from the level of low to that of high water, and consequently corresponds with it in elevation. The notch in the land, the Road, thus represents the transition period when the strait was partly open, partly closed during each tide, and the pause, as it were, in the fall of the sea-level thus occasioned. Once the barrier was fully established and the strait permanently shut, the regular continuous fall of the water, and the consequent uniform unbroken slope of the declivities would recommence, and continue till a second col was reached, when a second line would form.

The formation of lines of erosion or roads at the level of these cols seems thus the necessary result of the damming up of the western tidal currents during the gradual rise of the land. No one can doubt that the rise in the sea-level thus occasioned would be very considerable, who has observed the strong currents that run among the western isles, or in the wider channel between Cantyre and Ireland to the south of this tract of coast, and round Cape Wrath and through the Pentland Firth on the north. Were the reefs in the latter, marked by the Merry Men of Mey and other too well-known breakers, brought to the surface, there can be little doubt that the sea-level would rise perceptibly both on the coast of Caithness and among the Orkney Islands. It must, however, be remembered that I ascribe the roads not directly to this rise of the sea-level, but to the virtual pause or halt it occasioned during the uniform rise in the land. The duration of this halt would be determined by the rapidity of the rise of the land, and the difference between high and low tide. If the land rose, as in some parts of Scandinavia, only three feet in a century, then the sea-level might remain nearly permanent for the same or even a longer period. But a very few years might suffice to form well-marked lines; and probably a more rapid rise might conduce to their preservation. Might it not be possible, from the breadth of these roads, to estimate the rate at which the land was rising during the time of their formation?

There are a few special points that require to be noted when applying this theory to the different glens and roads. Glen Gloy is very deep and narrow near the top, but has a wide open mouth towards Loch Lochy on the west. The pass at its head to Glen Roy, though not broad, still bears a considerable proportion to the dimensions of the glen, so that the height of the water would be greatly affected by its being closed. In this glen there is no second col to form another line; and as it has no direct connexion with Glen Roy or Glen Spean, the changes in them did not influence it, and the lower lines consequently do not appear in it. The line seen is also more marked on the western than on the eastern side of the glen, the latter having been more exposed to the open sea.

Glen Roy, again, has a wide, open mouth, and contracts gradually towards the top. The pass there to Glen Spey has considerable breadth and a flat horizontal bottom, so that by its being closed a great outflow of water would be suddenly checked. The second col in this valley, or that of Glen Glaister, lies so near the foot of the glen that it might be thought that the shutting it would produce little effect on the level of the western waters. But there is another col almost on the same level on the south-west declivity of Craig Dhu, where a small hill projects from it into Glen Spean, greatly contracting the width of this latter glen (Spean). Hence the second line continues further down Glen Roy than the first, and is more distinct towards Glen Spean. The shutting of the Pass of Maccoul would affect the level of the water both in Glen Spean and Glen Roy. Hence the greater extent of the third or lowest Glen-Roy line, both in that glen and in Glen Spean, where it stretches from beyond Loch Laggan on the east, till it dies out on the declivities of Ben Nevis, then washed by the open western sea.

This view of the mode of origin of these parallel roads thus fully meets the objections stated to the marine theory. The agreement in level of the lines and cols is no mere chance coincidence, but the direct result of existing conditions. The roads only occur in these valleys and in particular portions of them because in these only were the conditions essential to their formation found. Such valleys, opening by wide mouths to the west, and drained by broad straits liable to be suddenly shut during the rise of the land, are not of frequent occurrence, and of course are quite unknown on the east side of the island. On the other hand, no sufficient reason appears in the lake theory why such detritus or glacier-formed lakes should have occurred here, and this at four successive levels, and in no other part of Scotland. Further, this view is in harmony with the most approved theory of geological change, appealing only to existing causes, and demanding no sudden or violent revolutions, but simply the slow, continuous regular rise of the land.

Since the above was written, Colonel Sir Henry James has kindly furnished me with a note of the elevation above the sea-level of the roads and cols. This shows that the Glen-Gloy road (No. 1 in Chambers's 'Ancient Sea Margins'), 1168 feet, exactly corresponds with the col to Glen Roy. The upper Glen-Roy road (No. 2 of Chambers), 1149 feet, is one foot below the col to Loch Spey, 1150 feet. The middle Glen-Roy road (No. 3, Chambers), 1065 feet, agrees with the col to Loch Laggan. But the lower road (No. 4, Chambers), 856 feet, is six feet above the col to the Spey, 850 feet.

Discussion.

Sir Henry James stated that he had given particular instructions to the officers in charge of the survey as to the accurate levelling of the roads. Captain White had informed him that there was some question as to the existence of more than one road in Glen Gloy. There could, however, be no doubt as to the general correspondence of the levels of the terraces at different points. With regard to local variations in the level of the sea, he stated that the mean sea-level was found to be remarkably constant. He considered the question as rather physical than geological. In that district was a country every feature of which had been modified by glaciers; and there was therefore no difficulty in conceding the existence of glacier lakes. There was, moreover, every probability of a country so cut up by such deep valleys having in places enormous accumulations of ice, and especially in Glen More. The difference in level between the beds in Glen Gloy and Roy was 20 feet, which could hardly be accounted for on the marine theory. Nor are there any similar terraces in neighbouring glens, such as ought to be there on that theory. In so exceptional a district, with Ben Nevis acting as a buttress at the east end of Glen More, against which and upon which ice would accumulate, that theory was the best which accounted for the terraces by the lakes having been formed by the intervention of glaciers blocking the valleys, as, according to this theory, it would not be likely that the levels of the roads in the different valleys would be the same, seeing that the ice-barriers of the different valleys would probably not break at the same moment. The levels were taken at the middle of the slope of the terraces.

Prof. Ramsay entered into the history of the theories for accounting for the terraces; the first of which, that of Prof. Agassiz (in 1840), accounted for them by a great glacier damming up the valley, and from time to time declining in height. The glacial theory, on which this view rested, had to some extent been doubted, but eventually had been almost universally accepted even by its first opponents. He next cited the works of the late Mr. Robert Chambers as to the existence of old sea-margins, pointing to a gradual sinking of the sea or a rising of the land. There could be little doubt that a great part of Scotland and of the northern part of England had been at one time covered with glaciers, as had also been the case in other parts of Europe. Unless the whole country had been submerged, and then came up again by a succession of jerks, it seemed impossible that such terraces could have been formed by the sea and still have remained in existence. If, however, there had been great oscillations in temperature, it seemed possible that during the decline of some transverse glacier the varying levels of the lake might have left terraces, traces of which might still be preserved.

Mr. L. Lyell thought that Prof. Nicol's view, that the different heights of the terraces in Glen Gloy and Glen Roy were due to a great pressure of water coming from the west, could hardly be sustained. If the sea had stood at that level, Scotland would have been an archipelago, and differences of level, such as the terraces indicated, could only have resulted from great tidal action, such as is the case in the Loffoden Islands. He held that there was no evidence to show that such a state of things had existed in the present case. As to the coincidence of the level of the roads with that of the cols, he did not think they were explained on the marine hypothesis. At the base of Prof. Nicol's speculation was an assumption in which he could not agree. It was that the coating of detritus which covered the hills was of marine origin. On the contrary, he held it to be subaërial. The fragments of rock were subangular, little weathered, and altogether such as might be found in any subaërial detritus. At Loch Assynt the beach of the freshwater lake consists of fragments of red and white sandstone, unrolled, and but partially water-worn. The beach of Loch Maree, a land-locked arm of the sea, was composed of fragments of the same rocks; but these were rolled; and he believed that this difference was due to the tide, which was absent in Loch Assynt and present in Loch Maree. The materials on the roads of Glen Roy, when he examined them in 1869, much more nearly resembled those on the shores of the freshwater lake than those on the shores of the marine and tidal Loch Maree. He suggested the necessity of the observation of the nearest parallel cases which could be found in cases where no experiments were possible. The phenomena shown in Glen Roy were then compared with similar appearances at the Märjelen See, a small glacier-bound lake in Switzerland, which fulfils in nature all the conditions which the theory of the glacier-lake origin of the Glen-Roy terraces required.

Mr. Gwyn Jeffreys renewed his protest against regarding these beds as marine unless marine remains were found in them. In

Prof. Nicol's former paper mention had been made of rolled boulders. These occurred at Glasgow and elsewhere covered with *Balani*. As, however, no marine remains had been found in Glen Roy, he adopted the freshwater or glacier theory.

Mr. Daintree, reasoning from observations made in tropical countries, asked whether the terraces might not have been formed during the change of seasons from summer to winter.

Mr. Evans regretted that no one else was present who would in any degree advocate the author's views. He pointed out that if the surface of the rocks below the detritus in Glen Roy was glaciated, the probability was in favour of the superficial drift being of marine rather than of subaerial origin. He much doubted whether Ben Nevis, or any of the mountains of the district, offered a sufficient gathering-ground for any such glacier as that supposed in the fresh-water theory, assuming the climate to have been such as would have admitted of a large lake in Glen Roy. He suggested the possibility of the openings through which the sea would gain access to the district having at the time of the last submergence been to some extent choked with ice, which thus checked the tidal action inland from the present coast; and thought that possibly both glaciers and the sea had together contributed towards the formation of the terraces. These, he observed, were by no means confined to Glen Roy itself, but were to be seen on a large scale and at a lower level in the valley of the Spean, if not elsewhere.

Mr. Prestwich observed that both sides of the question had an *à priori* argument in their favour. There was no doubt of the almost universal glaciation or of the depression below the sea to a depth of at least 1000 feet, and therefore that marine action was possible. The circumstance of the cols marking the height of each terrace was, however, strongly in favour of the fresh-water theory; but, on the other hand, there seemed an absence of sufficiently elevated land in the Glen Roy district for the origination of a glacier such as was required by this theory.

Prof. Duncan, suggested the necessity of actual sections being made to show the nature of the terraces and the condition of the rocks below. He referred to a case on a much larger scale in the Yungma valley of East Nepaul, recorded by Dr. Hooker, in which the phenomena of Glen Roy were repeated on a larger scale, and in connexion with each terrace a glacier and its moraine could be traced.

March 20, 1872.

George Attwood. Esq., of San Francisco, California; Walter Percy Sladen, Esq., Eley House, Halifax; and William Spencer, Esq., Mining Engineer, Sunderland, were elected Fellows of the Society.

The following communication was read:—

On the Wealden *as a* Fluvio-lacustrine Formation, *and on the* relation *of the so-called* "Punfield Formation" *to the* Wealden *and* Neocomian. By C. J. A. Meyer, Esq., F.G.S.

Amongst the suggestions which have from time to time been offered in explanation of the origin of the Wealden strata of the south-east of England, the one which has hitherto obtained the most favour amongst geologists is that of their accumulation as the delta of some great river open to the sea.

That these strata are mainly of fluviatile origin can hardly be doubted; that they formed the delta of a single river is not so certain; and with respect to their mode of accumulation, it is at least open to question whether they do not represent, as a whole, a lacustrine rather than an estuarine deposit.

It may seem at first sight of little consequence which of these views is held to be correct. I shall attempt to show, however, that the question is one of real importance, not only as regards the history of the Wealden strata themselves, but with respect also to the relation of the Wealden beds to certain Neocomian strata with which they were, no doubt, in part coeval.

To the fluvio-lacustrine origin of the Wealden strata which I propose to advocate, many objections may of course be raised; but these I shall not anticipate, the objections to their purely fluviatile or estuarine origin appearing to me to be of greater weight. The exceedingly quiet deposition of much of the sedimentary strata, the almost total absence of shingle, the prevalence, both numerically and specifically, of such species of mollusca as delight most in quiet waters, the comparative absence throughout the greater portion of the series of broken shells such as always abound in tidal rivers, and, I believe I may say also, the total absence of any trace of drift wood perforated by mollusca in either the Purbeck or Wealden strata, all seem to me to point to the same conclusion—namely, to the accumulation of such strata beneath the waters of a wide but shallow lake, whose superfluous waters during the middle Wealden era escaped, indeed, to the sea, but only by some narrow outlet*, and whose area was perhaps occasionally, though rarely, invaded by the ocean.

It is not my purpose to define the boundary of such lake, the outline of the land-surface of the period, or even the source or bearing of its rivers. The most I will now venture to suggest is this—that the country of Western Europe at the time of the deposition of the Wealden was not simply, as has been often supposed, a land traversed by some great river "laden with spoils from a distance," but that such land held within itself at once the origin and point or points of outfall of the Wealden rivers.

There is probably no fact in the past physical history of Europe more generally admitted by geologists than that of the steady increase of land towards and at the close of the Oolitic period. Such

* It is more than probable that the waters of the Purbeck and *later* Wealden period had no outlet whatever to the ocean.

land rising from beneath the wide-spread ocean of the Oxford Clay and remaining but partially submerged during the accumulation of the Portland strata, gradually enclosed as it were within itself one or more centres of depression. These, cut off, it may be, at first but partially from the retreating ocean, and receiving as catchment-basins the accumulated drainage of the older and newer lands, passed gradually and with many changes of condition from inland seas or branches of the sea to wide but shallow lakes—the Wealden lakes, as I would venture to suggest, of England and of Hanover.

It would be difficult, perhaps impossible, to determine the precise period at which such land had attained its greatest ascendancy, whether directly at the close of the Portlandian era or at some later time; and it matters little to my present purpose when such period may be fixed. Certain it is that with the close (or, more correctly, towards the close) of the Wealden epoch, the gain was once more on the side of the ocean.

Allowing, then (as all will, I think, allow), that the gain of the ocean on the land at the close of the Wealden period involved sooner or later the whole Wealden area of the south-east of England, the second object of this paper is to show that the intrusion of such ocean into the Wealden basin did not at once, or for a long period, cut off the flow of rivers into what had now become a part of the Neocomian sea.

There are thus two separate suggestions which I propose to put forward in this paper in relation to the Wealden and its rivers:—

1st. That the Wealden strata are a fluvio-lacustrine rather than a purely fluviatile or fluvio-estuarine deposit;

2nd. That the Wealden rivers continued in existence, although probably in much diminished volume, during the accumulation of most of the succeeding Neocomian strata.

1. In attributing to the Wealden formation a fluvio-lacustrine origin, it is necessary to refer to a nearly similar origin the greater portion of the Purbeck strata; and this I have no hesitation in doing. The adjacent land-surfaces were probably the same during both these periods; the drainage-area was, there is little doubt, also virtually the same. And, excepting that the species altered with the flow of time, the fauna of the one formation is, with few exceptions, the counterpart of the other.

The Purbeck strata, as a rule, contain little evidence of direct fluviatile action. Drift wood, or the remains of vegetation, is rarely to be found in them, except in direct connexion with a terrestrial surface. The insects and insectivorous mammalia whose remains are occasionally present were probably inhabitants of the immediately adjacent shores, of sand-dunes, or of some small islands. Few geologists can regard the Purbeck marble as other than a quiet-water, if not a lacustrine, deposit; and the resemblance of the "limestone with flint nodules" of the Purbeck to the freshwater lacustrine strata of Cantal, in Central France *, is certainly remarkable.

It was shown by Professor Forbes, in his description of the Dorset-

* Lyell, El. of Geol., "Lacustrine strata of Auvergne."

shire Purbecks, read before the British Association in 1850, that a change from freshwater to marine conditions took place suddenly on at least two occasions; and it is evident that such changes took place at once over the greater part, if not the whole, of the Purbeck area. It is on these occasions, and on these only, that true marine fossils (*Pecten*, *Avicula*, *Thracia*, *Hemicidaris*) make their appearance in the Purbeck strata. It is certainly a fact that there is no real intermingling of freshwater and marine genera in the same stratum; the abrupt change from freshwater to marine conditions is again and again succeeded by a more gradual change from brackish to freshwater. Now it seems to me that such sudden change from freshwater to marine conditions, and the gradual return to freshwater, accords well with the idea of the intrusion of the ocean into a lake or basin of fresh water, and does not accord with the results usually due to tidal action; for it is evident that the freshwater fauna of the Purbecks is lacustrine rather than fluviatile, while the brackish-water species are such as might well have lived in waters not open to the sea.

Judged therefore by its fauna, no less than on stratigraphical evidence, the condition of the Purbeck basin was probably from its commencement rather that of a lake, a series of lagoons, or even of an inland sea, than of an estuary in the ordinary meaning of the word. Its waters were mostly shallow,and possibly always brackish some portion of its area, as in those more distantly removed from the influx of rivers, becoming locally almost salt at times from actual evaporation.

That its waters were for the most part shallow there is abundant evidence in many portions of the Purbeck strata; and taking into account the probable climatal conditions of England during the Purbeck and Wealden periods, as shown by its flora, the occasional drying up, or even evaporation to saltness, of portions of such a lake or inland sea can hardly be thought an unreasonable supposition.

I admit that the evidence as to the effect of evaporation in producing saline conditions in these strata is not clear; but that some such action was in progress during the accumulation of the Purbeck strata I shall attempt to prove by specimens from Durlstone Bay.

These specimens, which Professor Morris tells me are both rare and curious, are cubical siliceous pseudomorphs of crystals of salt. The stratum in which they occur is crowded with fossils of purely freshwater genera (*Unio*, *Physa*, *Valvata*, *Paludina*, *Planorbis*, besides innumerable valves of *Cypris* and seed-vessels of *Charæ*), the preceding and succeeding strata containing also the same fossils without any intermixture of marine species. But the importance of the evidence afforded by the accidental preservation of salt crystals in such a position consists in the fact that the surface of the stratum which contains them is traversed by sun-cracks, proving, as it seems to me, that the saline conditions of the moment were quite possibly the result of rapid evaporation.

It is therefore by the coexistence within a comparatively wide area of a fauna suited respectively to freshwater and brackish-water conditions, and by the interchange of such conditions over portions of the same area, supplemented by an occasional intrusion of the ocean, that I would account for the alternation of freshwater, marine, and brackish-water fossils in the Purbeck strata; for, as I shall endeavour to show more fully with respect to the Wealden, neither the conditions of accumulation of the sedimentary strata, nor the life-conditions of its fauna appear to be sufficiently in accordance with an estuarine position.

It is not yet known with certainty whether the English Purbeck strata are anywhere in direct sequence with the marine Portlandian series, unless such proves to be the case at Swindon—or whether, as in the Isles of Purbeck and Portland and apparently in the Vale of Wardour, the Portland beds had been everywhere elevated before the commencement of the lower Purbecks; but we do know (and this is an important point in their history) that the Purbeck beds lie almost entirely within the former boundary of the Portlandian ocean. This is to me an important fact, as it tends to prove what I have already suggested, that the so-called "area of subsidence" in which I suppose the Purbeck strata to have originated was itself a portion of an older, larger, but equally subsiding area of the Portlandian ocean.

Now there would appear to be certain partially understood laws in operation in nature in relation to areas of subsidence which seem to have a bearing on the present subject, the general results of which may be stated as follows:—first, that the central portion of any subsiding area will sink faster than the parts nearer to its margins; and secondly, that such subsiding areas have a tendency to diminish in extent. If, therefore, as I have supposed, the Purbeck beds originally occupied such an area of subsidence, one might expect to find that the extent of the succeeding Wealden basin would be less than that at one time covered by the Purbeck waters; and such, I believe, is in reality the case.

Purbeck strata are described by Fitton as occurring at Coombe Wood in Oxfordshire*, at Long Crendon towards Thame†, and in other places where they are covered by the higher beds of the Neocomian.

The point of junction of the Purbeck and Wealden beds is unfortunately nowhere very clearly observable; yet, as the two formations have been always taken as continuous, I shall so consider them.

In turning from the Purbeck to the Wealden, one finds immediate evidence of the increase of fluviatile action. The abundant fragmentary remains of ferns and other terrestrial vegetation in the Hastings Sands and lower portion of the Wealden beds, the tree-stems, and the bones of reptiles were doubtless all brought down by rivers to their present resting-places. The sand and clay, the pebbles of "quartz and jasper" ‡ may also all be traced to river-action. It is clear, however, on examination of these strata, that such action was intermittent, and that its effects varied greatly at different times over different portions of the Wealden area. There is throughout the

* Geol. Trans. 2 ser. iv. p. 275. † *Ibid.* p. 281.

‡ Tilgate-beds. Mantell's Geol. Suss. (1827), p. 29.

thickness of these Wealden strata a continual, although oft-repeated, variation in the character of the deposits; yet one might venture to say, even on stratigraphical evidence alone, that nine tenths of the whole was quietly accumulated. The fine-grained sandstone and quartzose grits of the lower beds, the stiff red clays of the middle, and thinly foliated "marl with *Cypris*" of the upper Wealden might all be of lacustrine origin, and yet include both tree-stems and the bones of reptiles. There is, indeed, in these, again, as in some portions of the Purbeck strata, a strong resemblance to the Tertiary lacustrine beds of Central France.

The molluscan remains of the true freshwater Wealden strata are too well known to need remark. The mode of their occurrence, differing here and there according to the condition of the strata in which they are imbedded, appears to agree very well with the idea of a combined fluvio-lacustrine origin. Judged by these fossils and the mode of their occurrence, the waters of the lower and middle Wealden must have been extremely shallow and much disturbed at times by river-action. The finely laminated strata of the Upper Wealden (and I include in this the so-called "Punfield-beds" of Atherfield and Compton Bay) are such as, on the contrary, belong to deeper waters, and rarely, if ever, show traces of disturbance. If, then, the Wealden beds, like those of the Purbeck, originated in an area not open to the sea, the varying condition of the strata must in some way be accounted for.

Now the evidences of river-action as seen throughout the Wealden area point to two facts, which are, indeed, very generally admitted—namely, first to the elevation, secondly to the slow depression of the surrounding country during the Wealden epoch. Its elevation was probably the greatest during the accumulation of the lower and middle Wealden strata, at which time the force and carrying power of the Wealden rivers, as looked at from my point of view, was in excess. Its depression from this time onwards was probably continuous, diminishing the river-action, adding depth to the Wealden waters, and placing eventually the Wealden lacustrine area below the sea-level.

Now it is a well-known fact that the higher beds of the Wealden are not only extremely uniform in character, proving to some extent their deep-water origin, but also contain freshwater fossils up to their very junction with the Neocomian strata. It is a fact also that the change from Wealden to Neocomian was an abrupt change; the passage bed, as may be seen at Atherfield and Redcliffe, in the Isle of Wight, and as I have seen it also at Haslemere* and Sevenoaks, is but a few inches in thickness, and consists of the same slaty clay as the underlying Wealden strata of which it forms a part. It contains, however, a curious assemblage of freshwater and brackish-water fossils, some of which are found in no other stratum of the Wealden with which we are at present acquainted. The most noticeable of these is a shell mentioned by Fitton in 1843 as pro-

* See also a note by Mr. Salter, Mem. Geol. Survey, Isle of Wight (1862), p. 18.

bably a new species of *Cerithium*, but subsequently figured by Mantell under the name of *Potamides carbonarius* (Mant. Geol. Isle of Wight, pl. vi. f. 5). It is apparently rare at Atherfield, but occurs abundantly in the same stratum at Sevenoaks and Haslemere. The mode of its occurrence is peculiar: the shells are frequently eroded or waterworn as to their surface; they are often broken, and exhibit the appearance of having been washed or drifted into their present position. I believe the shell to have been in habit a true *Potamides* rather than a *Cerithium*, as suggested by Professor Forbes *, that it was semiaquatic and was forced into its present position at the time of the irruption of the ocean into the Wealden area. A small species of *Ostrea*, a *Cardium*, and a species of *Corbula* or *Potamomya* occur occasionally in this passage-bed at Sevenoaks and Haslemere, and also at a lower level in the Isle of Wight, and clearly indicate, where present, the temporary prevalence of brackish water. I shall have to refer again to these species, and to the conditions under which they occur.

The lowest portion of the succeeding (Neocomian) stratum, which rests upon the passage-bed I have just described, includes, in the words of Fitton, "a large quantity of a kind of gravel containing numerous fragments of fish-bones." It is just such an accumulation of sediment as would result from the dispersion of shore-deposits over the floor of a moderately deep lake. The fish-bones mentioned by Fitton are those possibly of inhabitants of the Wealden waters; their presence at the junction of the two formations may be due to the suddenness of their destruction by the change from fresh to salt water.

2. With respect to the second subject of this paper, which relates to the existence of the Wealden rivers after the close of the Wealden era, there is unfortunately much difficulty in obtaining evidence. The existence of such rivers during the accumulation of the Neocomian deposits has been indeed inferred by Fitton and other eminent geologists; but to the present moment proof is wanting. It is, however, just one of those points in geological history on which, proof being wanting, indirect evidence becomes important; to obtain such evidence, one must look back in the first place from the Neocomian to the Wealden era.

The close of the Wealden formation, as seen at Atherfield, Sevenoaks, Haslemere, and other points in the south-east of England, resulted, as I have supposed, from the depression of a lacustrine area beneath the sea-level. I have supposed that such depression was effected gradually, but that the final intrusion of the ocean into the Wealden basin was a sudden intrusion, such a one as might have resulted from the destruction of some previously existing barrier between the ocean and a freshwater lake or inland sea.

Now I have shown, and it is besides a well-known fact to most geologists, that the freshwater Wealden beds of Kent, Surrey, Sussex, and Hampshire are everywhere at once succeeded by the marine "Atherfield beds" of the English Neocomian. It has been shown by Mr. Godwin-Austen and others that these "Atherfield beds" are

* Mem. Geol. Survey (1862), p. 18.

confined to the Wealden area, and that the highest or "Folkstone beds" of the Neocomian series alone extend beyond such area. There is, therefore, little room for doubt that the rivers of the later Wealden period were rivers still after its close—that as at one time they poured their waters into the great Wealden basin, so at a later time they still flowed on into the Neocomian sea. The drainage-area of the adjacent lands remained well nigh the same; the rivers were still almost the same; their catchment-basin had changed meantime from Wealden to Neocomian.

The traces of terrestrial vegetation which are of such comparatively frequent occurrence in the English Neocomian strata have been always attributed to river-action. Such remains occur in many localities and on various horizons in the Lower Greensand, but are most abundant towards the middle and upper portions of the formation. I have seen fragments of drift wood in the *Perna*-bed in Surrey; and it has been recorded from Atherfield; but it is rare at so low a level. Coniferous wood occurs, according to Mantell, in the "Cracker's rock" of the Isle of Wight; it is common in the Kentish rag of Hythe and Maidstone, and is yet more abundant near the base of the Folkestone beds at Shanklin in the Isle of Wight and at Nutfield in Surrey. Fossil resin occurs at Shanklin, and has been found by Mr. Simms in Kent on about the same horizon—namely, near the base of the Folkestone-beds. Leaflets and smaller fragments of a Wealden fern, the *Lonchopteris Mantelli*, have been found throughout nearly the entire formation*, but are apparently most abundant at Shanklin.

The occurrence of remains of *Iguanodon Mantelli* and of freshwater turtles in the Kentish rag of Maidstone is too well known to need remark, except as a proof of the continuance of river-action. The last evidence I shall offer on this point relates to the occurrence of remains of the great Wealden reptile at a yet higher level than the Kentish rag. From information obtained from quarrymen I had long suspected the presence of bones of the *Iguanodon* in the Bargate stone of Surrey, and I was last year fortunate enough to find the unworn tooth of an *Iguanodon* in the upper beds of the Bargate stone near Guildford.

Taken broadly, therefore, and without reference to special periods, I believe that the same land poured its waters into the Neocomian as previously into the Purbeck-Wealden basin of the south-east of England—that such rivers were several in number, and flowed perhaps at once from Central and Western France and from the old and newer lands of Western England.

3. I come now to what is after all the really important point in this paper; it is one on which, as a young geologist, I must ask the forbearance of this Society, and especially of those geologists from whose expressed opinion I am forced to differ. I refer to the relation of the so-called "Punfield Formation" of Mr. Judd to the Neocomian and Wealden strata of the south-east of England.

At the time the paper on the "Punfield formation" was read

* Mem. Geol. Survey, "Isle of Wight" (1862), p. 13.

before this Society, I had not seen these beds *in situ*, and was ready enough to accept the suggestions then put forward in regard to their position. Since that time, however, I have most carefullyexamined the Punfield strata, and find it impossible to agree to the position assigned to them by the author of that paper.

It is not my purpose at this time to go closely into the details of the section, as I hope to do so on another occasion; but, with permission, I will here state broadly the points of difference between us.

Taken broadly, the Wealden beds, no less than the succeeding representatives of the Neocomian strata of Swanage Bay, put on a shore- or littoral appearance as compared with their recognized equivalents in the Isle of Wight; and all, even on Mr. Judd's own showing, thin out rapidly to the westward. Yet one is asked to believe that the shallow-water, almost purely marine Punfield beds of Punfield are equal in position to the deeper and almost purely freshwater strata of Atherfield and Compton Bay. This seeming contradiction is so far, however, merely a question of probability, and might, but for other reasons, be even as stated. But a far more important point in the Punfield section has been hitherto apparently either overlooked or disregarded; I refer to the condition of the beds beneath the "marine band," and between that and the so-called "variegated beds" of the Wealden.

The cliff-section, fig. 1, given in Mr. Judd's paper on the Punfield Formation*, illustrates very fairly the position of these intervening strata. The beds are of no great thickness, possibly not more than from thirty to forty feet in all, of which the upper part alone is visible. The whole group, I suspect, is argillaceous.

My attention was called to this portion of the section by observing the resemblance of the beds beneath the "marine band" to the well-known "Lobster-clay" of Atherfield and Surrey. These beds were but slightly exposed at the time of my visit; but with some trouble I contrived to trace them from the "Marine band" downwards to a depth of from fifteen to twenty feet, where they rested on a hard seam or stratum of gritty ironstone from one to three inches in thickness. Below this hard stratum the beds were covered for some distance by vegetation; and the next strata visible were coloured sands and clays of the Wealden.

The clay between the "Marine band" and the band of gritty ironstone is stiff and nearly uniform in character, and appeared at first sight to be wholly unfossiliferous. After a long search, however, and by breaking up the dryer masses of the clay, I obtained first traces, and finally crushed but otherwise nearly entire specimens of a truly marine fossil, a species of *Arca*. Imperfect as were these specimens, I had no doubt that they represented the *Arca Raulini* of D'Orbigny—a species with which I was well acquainted, and which is one of the commonest fossils of the Atherfield clay.

Beyond this evidence as to the marine origin of the clay-bed my search was unrewarded; but the suspicion aroused in my mind by the similarity of these clay-beds to the Lobster-clay of Atherfield

* Quart. Journ. Geol. Soc. vol. xxvii. p. 212, fig. 1.

has been since, to some extent, confirmed; for I have learnt that a fossil lobster similar to those of Atherfield had been some time previously obtained from this very stratum. The specimen is now in a small local museum at the village of Corfe, in the Isle of Purbeck.

The hard thin band of ironstone-grit at the base of these clay-beds did not appear to contain fossils; it represents unquestionably the stratum *c* described by Mr. Judd as forming the base of the so-called "Punfield formation" at Worborrow Bay* to the west of Swanage, and in which *marine* fossils were recognized by Professor E. Forbes.

I examined most carefully the whole of the exposed strata from the "Marine band" upwards to the junction of the Neocomian sand with the Gault, and obtained many fossils from the two principal shell-beds.

The "Cypridiferous shales with bands of limestone" containing freshwater fossils, described as occurring at the top of the "Punfield beds," I could not discover, although they may possibly be present in that position. The "beds of sandstone containing *Cyprides* and casts of *Cyrena*" I could not find; and I may state at once that in a two days' search I failed to find either a single valve of *Cypris* or the faintest evidence of any freshwater fossil in any portion of the series; and I understand that Mr. Judd himself was equally unsuccessful.

It is true that the thin-bedded sands and clays with lignite and fragments of carbonaceous matter so common in this section have some resemblance to freshwater deposits, but not more than the marine sands and clays with lignite of the Eocene Lower Bagshot beds of Whitecliff Bay, or even than some portions of the Lower Greensand.

But, it is said, the fauna of the Punfield beds proves their position as a portion of the Wealden. What is this fauna? It is a semi-marine or brackish-water fauna, the fauna of a shallow-water or littoral deposit, and so far agrees with the condition of the strata. But it is also a mixed fauna, composed of three elements, which require to be considered separately. It includes first, a set of species peculiar to the locality so far as the British strata are concerned; it includes, secondly, a fauna scanty in species but individually numerous, which belongs, as it were, of right to the Purbeck-Wealden area; and, thirdly, it includes a fauna extremely common in the Lower Greensand.

In the first of these groups I include a set of marine or brackish-water mollusca peculiar to this locality and to the coal-bearing strata of Eastern Spain; and these, as I take it, are of no value whatever in proving the position of the deposit, even though, as Mr. Judd has so clearly shown, they prove its age.

In the second group I include at most three or four species of brackish-water mollusks; but these are specially worth notice; they are a *Cardium*, a small *Ostrea*, a *Corbula* or *Potamomya*, and a species of *Mytilus*. Now, in studying the fossils of the Purbeck-

* Quart. Journ. Geol. Soc. vol. xxvii. p. 216.

Wealden, one is constantly brought face to face with these four genera; they come in, as is well-known, soon after the commencement of the Purbeck strata, and continue to appear at intervals up to the base of the Neocomian, and, as I suspect, to a much higher level. The species change somewhat in time, as do the species of *Cypris* and *Paludina*, with which they alternate; but there they are. The reason, as I take it, is that throughout the period they never wholly left the Wealden area; they are of no value in point of evidence.

The third group includes a set of species common enough in the Neocomian beds of Atherfield and Shanklin, and some of them even yet more common in Kent and Surrey; of these the following have been determined:—

Ammonites Deshayesii, *Desh.*
Natica lævigata, *Desh.*
Exogyra Tombeckiana, *D'Orb.*
E. Boussingaultii, *D'Orb.*
E. sinuata, *Sow.*
Anomia lævigata, *Sow.*
Plicatula asperrima, *D'Orb.*
P. Carteroniana, *D'Orb.*
Cardium impressum, *Desh.*
C. subhillanum, *Leym.*
Corbula striatula, *Sow.*
Pholadomya semicostata, *Ag.*
Pholadidea.
Teredo.
Venus.
Tellina vectiana, *Forbes.*
Astacoid remains (in the clay at the base of the section and in the lower shell-bed).

What, then, is the true bearing of the evidence to be obtained at Punfield in regard to these Punfield strata? The physical evidence, though inconclusive, certainly does not favour the idea of their correlation with the Wealden beds of Atherfield or Surrey. The lower beds, from the ironstone band to the "marine band" inclusive, are certainly marine, and contain no freshwater fossils: the middle and upper beds bear traces of having been accumulated under the influence of fluviatile action, but are in other respects undoubtedly marine. The "grey Cypridiferous shales" a few feet only in thickness, which I could not find, but which are said to come in at the top of the Punfield beds, are, to my thinking, of very little importance, and for this reason, that they are no more than proof positive of the existence *at this point* of fluviatile action, indistinct traces of which are so commonly apparent in the Neocomian beds at Shanklin.

The palæontological evidence obtainable at Punfield, although also to some extent contradictory, appears to me to be most strongly in favour of the correlation of these strata with the Lower Greensand, and not with the Wealden. Mr. Judd is no doubt correct as to the age of these Punfield beds of Punfield; I cannot possibly agree with him in placing them beneath the Neocomian beds of Atherfield.

To the author of this paper the so-called "Punfield formation" of the Isle of Purbeck is Lower Greensand and nothing else. The Punfield formation of the Isle of Wight is simply Upper Wealden.

The occurrence of a Spanish fauna at Punfield proves, if it proves any thing, that the Neocomian (Lower Greensand) series of the south-east of England and of Eastern Spain are, in point of age, equivalent deposits.

The accompanying sections (fig. 1) illustrate, somewhat roughly, the relation of the Neocomian series of Punfield to that of Worborrow Bay and Atherfield. It shows at a glance the comparative thickness of the strata in these three localities, with their relative distances from each other.

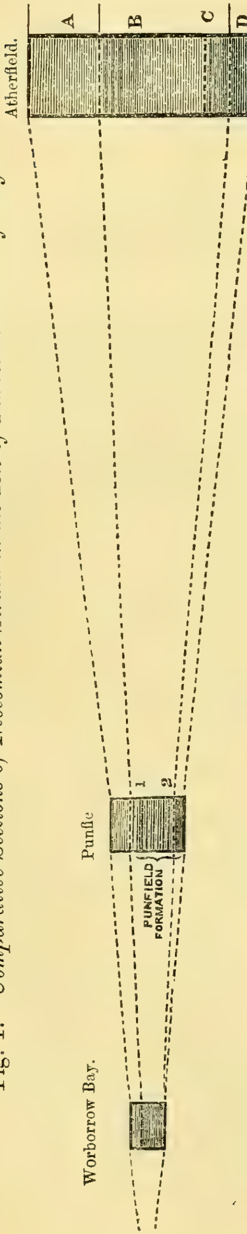


Fig. 1.—*Comparative Sections of Neocomian Strata in the Isle of Purbeck and Isle of Wight.*

A. Folkestone beds. C. Hythe beds. 1. Oyster-bed.
B. Sandgate beds. D. Atherfield beds. 2. Marine band.

Horizontal Scale, $\frac{1}{8}$ inch to 1 mile; vertical, about $\frac{1}{8}$ inch to 80 feet.

Discussion.

Mr. Godwin-Austen did not agree with Mr. Judd in calling the bed at Punfield the "Punfield formation;" it was merely a bed intercalated between beds of a different character below and above. There could be no doubt of the Wealden deposits extending over an area at least equal in extent to many of the freshwater lakes at present in existence; and the freshwater conditions exhibited by the Wealden must have been in existence during an immense length of time. At Punfield alone, however, was there evidence of the transition from freshwater to marine conditions; one reputed case seemed to be merely an instance of landslip. The change from one condition to the other might, he thought, be due to a very slight depression. The Neocomian series, such as was known to continental geologists, could hardly be recognized in Britain; and it was only during the last portion of that period that any deposits took place in this country. The phenomena of the Wealden deposits might, he believed, be traced over a much larger area than was commonly supposed, and certainly as far as Saxony. He considered that the same area of land continued through both the Jurassic and the Cretaceous times.

Prof. Ramsay thought that the Purbeck strata were connected with lagoons in contiguity with a large river rather than with inland lakes. These, from time to time, owing to oscillations of level, were covered with marine deposits. He did not think that the absence of gravelly deposits offered any serious difficulty in regarding the Wealden strata as having been formed at the mouth of a large river. It seemed to him probable that the sands and clays of the Wealden were due to ancient rivers on a large scale, though in some spots the beds were subject to the action of fresh and salt water alternately. To the east of Oxford the Lower Greensand beds were found at first to contain marine shells; but as they proceeded eastward fresh-water forms made their appearance, and in places at last predominated in beds of the same lithological character He regarded the Neocomian as, to some extent, a marine representative of the Wealden, though of later date.

Mr. Etheridge recalled the fact that Mr. Judd had correlated the Punfield fossils with those of the north of Spain, twenty-two species found in each being absolutely identical. He argued from this that the extent of the beds may have been far larger than might be supposed. In Hanover beds, characterized by different Ammonites, occurred in precisely the same order as in England at Speeton and elsewhere. He regarded the question between Mr. Judd and the author of the paper as not yet absolutely settled, though both had done much for its elucidation.

Prof. T. Rupert Jones remarked that the Purbeck-Wealden lake theory had not only been intimated by several previous writers, but had been illustrated by maps by Messrs. Godwin-Austen and Searles Wood, Jun. Whatever the direction of the main rivers, and whatever the extent of the lakes, the Rev. Osmond Fisher had shown that one river came in from the west. Mr. Jones instanced, in reference to the lake theory, the occurrence of Oysters, *Potamides*, and *Corbulæ* in the base of the Wealden at Poundsford—also that of the dwarf *Tornatella Popei* at Tunbridge Wells and Balcombe. He alluded also to the brecciated condition of some and the upturned position of other Wealden beds. In allusion to the small bivalve Entomostraca so often referred to, he regretted that they had not yet been fully described; a bed of them occurs in the Upper Portland at Hartwell before the Purbeck sets in. He concluded by saying that such general papers as the one under discussion ought to have detailed references to the writings and opinions of previous observers.

Mr. Hulke referred to the question of gravels being present in the Wealden, and stated that these were in some localities abundant, getting coarser in the beds furthest to the west. This increase in the coarseness of the gravel was suggestive of a river running from west to east. In the east of the Isle of Wight he had found remains of *Plesiosaurus*, a marine form, much more commonly than further west, which supported the same view. He mentioned beds between Brixton and Calbourne, in the Isle of Wight, which appeared to him strictly analogous to those in Worborrow Bay.

Mr. Jenkins disputed the identity of origin of the Purbeck and

Wealden formations,—limestones, remains of land-surfaces and "dirt-beds," and thick intercalated marine beds being abundant in the former and comparatively absent in the latter, and there being an equally marked difference in the organic contents of the two formations. He considered the Purbeck formation to have been deposited in a lagoon subject to occasional invasions of the sea, while the Wealden was in fact a large delta. Though both were of fresh-water origin, they were deposited under totally different conditions, the Purbeck formation representing a deposit of a lacustrine nature in tranquil water, and the Wealden a deposit in an estuary.

Prof. Morris, alluding to the pseudomorphs of salt mentioned by the author, stated that they had been somewhat compressed, and thus modified in form. They had also been found in other beds in the Wealden. He commented on the extension of the Wealden strata even to the south of Moscow. In the Oxford and Buckinghamshire area there was evidence of great denudation of the Purbeck and Wealden beds prior to the deposit of the Neocomian; so that great changes would seem to have taken place, giving rise to a great amount of denudation towards the close of the Wealden period.

Mr. Meyer agreed with Mr. Godwin-Austen and other speakers as to there having been a certain amount of denudation of the Upper Wealden beds prior to the deposit of others upon them; but this he regarded as merely local. It was the absence of shingle, rather than of gravel, to which he had alluded in his paper. He thought that there was a distinction to be traced between the Neocomian of the north of England, and that of the south, and that the middle beds of one were equivalent to the lower beds of the other.

April 10, 1872.

The following communication was read:—

Notice of some of the Secondary Effects *of the* Earthquake *of* 10th January, 1869, *in* Cachar. Communicated by Dr. Oldham, F.R.S., F.G.S., Calcutta. *With Remarks* by Robert Mallet, Esq., C.E., F.R.S., F.G.S.

The following communication has been delayed in being brought before the Geological Society in the expectation of receiving further facts from Dr. Oldham, or that he would publish a substantive account of his own results after his examination of the earthquake-region.

The latest communications received, however, by the writer from Dr. Oldham render it doubtful whether he will be able, consistently with the pressure of his official duties, to pursue the subject further; and as the facts which he has collected and well explained, of the production of enormous earth-fissures as effects of this earthquake, are of great importance, the writer has deemed it best to place them on record now, and to add to Dr. Oldham's account some remarks of his own as to the very striking secondary effects of this earthquake.

Cachar, the site of the earthquake of the 10th January, 1869, is a British Province of Eastern India, about 110 miles in length from north to south, by 60 or 70 miles in width.

Its boundaries on the north and south are Assam and Tipperah (an independent state), and on the east and west Munnepoor and Silhet respectively.

It is hill-surrounded, except on the south and west, and consists chiefly of extensive plains, through which many large and small rivers wind and wander through ever changing courses in deep muddy beds, in which they rise from 25 to 35 feet in the rains.

The chief river is the Barak, which is navigable for great distances, the Juroo and other tributaries being still large rivers; and all, flowing towards the west, discharge into the great Brahmapootra.

The plains, partly covered with jungle, but also largely cultivated for coffee, sugar, mulberries, and now, the writer believes, also for tea, consist of an enormous depth of loose material (the latest washings of the eastern branches of the Himalayas as these emerged from the sea), and, above this, of the prodigious mass of more or less dried and consolidated silt brought down for ages by the network of rivers forming the drainage of the existing land. The deep masses of clayey silt which constitute these plains, present that approach towards a stratified structure which always occurs in such deposits from muddy and slow-moving waters.

The silty mass, however, is not uniform in material at all depths; from the surface to a depth of 25 or 30 feet it consists of stiff clays, passing into mere sand-beds over large spaces. Over a widely spread but unknown area, these rest upon a bed, from 3 to 6 feet in depth, of slimy ooze, black, full of vegetable and other organic matter, putrid, water-soaked, very porous, and over large areas almost as mobile as a fluid—in fact, a wide-spread greasy quicksand—formed when the conditions supplying the rivers with silt must have differed considerably from what they are now, and over which, in thinner or thicker annual layers, the denser and now consistent mud of the surface of the plains has been gently spread out.

Owing to these conditions of the plains and circumstances of fall, the river-courses meander in the most sinuous and capricious channels, which are constantly changing their courses, and frequently inosculate with each other, or block themselves up here and there, and often overflow large areas of the plains in the wet season.

Such appears to have been the scene of the earthquake of the 10th January, 1869, or, rather, that of its meizoseismic area; for the shock or shocks were felt at Calcutta, and far away into Central Bengal.

The writer has received no clear information as to the apparent horizontal directions of shock at different points of observation, but gathers the general fact that the impulse was probably delivered from a centre of impulse somewhere beneath the hills to the east and north of Cachar. That point, however, is comparatively of little importance.

Although Dr. Oldham collected such facts with reference to overthrown objects, &c., as he deemed sufficient to enable him to apply the same methods as those which the writer employed for fixing the position and depth of the centre of impulse of the Neapolitan earthquake of 1857, and probably has, since the writer last heard from him, actually worked out that problem, its full solution would be but secondary in value to Dr. Oldham's observations as to the production of vast earth-fissures, which are of the highest importance as affording a better and more extended proof than has hitherto been presented anywhere else of the fact first urged by the writer in his original paper on the Dynamics of Earthquakes (Trans. Roy. Irish Acad. 1846), that earth-fissures, however vast, are only secondary phenomena—that is, are not produced directly by the transit of the elastic wave, but by the displacement of a portion of the surface-material of the earth by resolved forces, due to the motions impressed upon it by the wave. The observations by Dr. Oldham on the earth-fissures produced in the plain of Cachar have been fixed by means of a set of very fine photographs taken within a few weeks after the shock, and transmitted by him to the writer.

These are now laid before the Society; and several are worthy of an attentive study by everyone desirous of grasping through the eye the exact mechanism of those most curious and formidable movements.

It is time, however, to let Dr. Oldham speak for himself, through the following extract of a letter received by the writer from him, under date Calcutta, 29 March, 1869.

"Calcutta, 29 March, 1869.

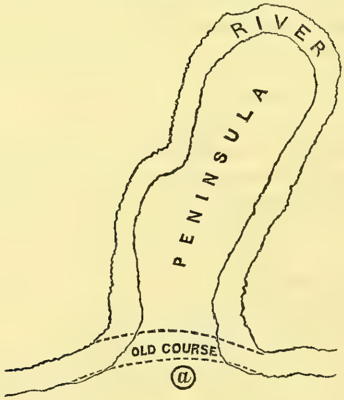
"Now for earthquakes; we had a sharp one on the 10th January, 1869. I had then just returned from Attok, and was too busy to go off at once and look after it; I did go in the beginning of February up to Cachar, where it was reported to have been worst; I went there, and thence across the hills to Gunbulty. I could not get into Munnepoor; for, just at the time all the available carriage of the country was taken up for an expedition against the Sooshuis, a tribe of Kookies, who had been committing outrages on the southern frontier of Cachar; so I had to abandon that; but at Cachar and other places I succeeded in getting some good observations, taking your noble Neapolitan earthquake as my guide. I think I have fixed the locale of the seismic focus, the depth, the velocity of wave-particle, &c.; I am just now waiting further measurements and information from a few other points to which I could not myself get; and you shall have all particulars when they are brought into shape. There happened to be a photographer up there at the time; he was on a professional tour; and he seized the opportunity of being there to take a series of views. They are not bad as photographs; but he is no artist, and selected his points of view without any judgment; still it was a great piece of luck that he was there. I have a series of these photographs specially procured for you; they shall go by the first steamer, a fortnight hence. The man sent them to me mounted, so that I can't send them by post.

"I quite long to send you all particulars, and to see whether I have really made any thing out of these. It is a first attempt, you know, on my part, and has necessarily been a hurried one; but, whether successful or not, you will, I know, appreciate the attempt.

"What accounts you may have had of the late earthquake I do not know; most of the telegraphic accounts we had here were greatly exaggerated, especially in regard to the fissuring and opening of the earth in many places, and the outburst of what they were pleased to call volcanic mud-craters, &c.

"It would be difficult to exaggerate the facts as to the fissuring of the ground in places; *but all this is only a secondary result.* The facts are these. The whole country is a great and widely extended alluvial flat, through which the rivers have cut deep channels, the banks being often 50 feet high, and commonly 30. As is usual in such cases, they wind about very much, and have filled and re-filled in the portions within these curvings. Cachar itself is just at the base of a long peninsula of this kind, just in the eye of this prominent bend of the river, while the flat peninsula is all of more recent formation (fig. 1). The distinction is perfectly known to the natives, who

Fig. 1.—*Diagram of changed River-course at Cachar.*



a. The town of Cachar or Silchar.

call the permanent portion *Kandy lands,* and the other more recently filled in of the old river-channels, *Bhurti lands*; *bhurti* is, literally, 'filled in.' Now for scores of miles together the whole of this *bhurti* land is composed of successive layers of stiff clay and mere sandy deposits some 25 to 30 feet thick, which, throughout, rest upon a bed some 3, 5 or 6 feet thick, of bluish silt or sandy ooze; this is very porous, and becomes highly charged with water, assuming, when thus charged, a dark bluish or nearly blackish colour. This bed is (throughout) at, or close to the present level of the water in the dry season, which is some 30 feet below its level in the rains and freshes; and in this way this porous bed has remained charged with water, while the beds above have become dry and more solid. This is the case for scores of miles down the river, as it is also the case at Silchar itself, and for miles higher up the river.

"Not a single fissure occurred in the solid and permanent part of the plain; but in every case where the *bhurti land* occurs they are numerous, countless. *In all cases these fissures correspond in direction with the general curve of the stream adjoining, varying with it, to every point of the compass within short distances*; and the rationale of the thing was clear: the shake came; the solid thickness of some 20 to 30 feet of clay above rested upon this bed of ooze full of water; this was agitated by the shake, and acted not only in generating a greater amount of motion by the water-wave, but acted also mechanically as a *slide* or smooth surface on which the enormous weight of the beds above began to move. These were unsupported along the river-channel, and have, therefore, all slipped in towards that channel, producing enormous and extensive fissuring, often filling up the channels of the river for the time, and driving back the water, and in one case entirely blocking up the river for six hours! These fissures, and other holes in the earth, formed those channels through which the tremendous superincumbent weight forced up the bluish silt from below, charged with water. This silt, or ooze, thus forced up overflowed the banks of the fissures or holes, *occasionally* in quantity sufficient to produce a mud-stream, *often* in just sufficient amount to produce a little lipping up within the hole, and then falling back to produce the effect of a conical hollow coated with mud or ooze. This was the cause of all the stories of smoke, steam, hot water, and sulphurous smells, &c. The first shot of dry mud, or fine sand, was taken for smoke or steam; the water was *foul*, and *hotter than surface-water at the time*, but only slightly so; and the sulphurous smell was nothing more than you would perceive in stirring up the mud at the bottom of any stagnant pool which had lain undisturbed for some time.

"This fissuring I noticed more or less extending down the river for more than a hundred miles! but in all cases confined, as I have said, to the river-banks, or other similarly placed localities. In fact, I believe, if the shake had occurred during the rains, when the river-channel was full, that nothing of the kind would have been seen; the water-cushion of the river would have held up the banks, to a very large extent at least. At one place close to Silchar (Silchar is the name of the town, Cachar of the district), where they had a road round the peninsula, near the edge of the bank (their favourite ride or drive in the evening) there was a brick drainage-conduit with a brick flooring; this has been split in two; and one half of the brickwork now lies 42 feet below the other half, which was untouched, and standing as before at the original level of the road. The bank here was about 53 feet above the dry-weather level of the river, which was the level at the time of the shock; and the whole of the 50 feet was on that side entirely unsupported; in the rains the water would have been at least 40 feet higher. Silchar town, though so distant from this (*i. e.* Calcutta), is not 200 feet above the level of the sea.

"The earthquake originated in the hills and north of Cachar. There are some curious and as yet, to me, unexplained cases of explosive noises, like separate discharges of artillery, distinctly audible and for some time at intervals, after the shock had ceased, but without any accompanying (at least perceptible) motion. One man, an engineer, declares he saw successive waves of undulation pass across his garden, where he was sitting, and that the motion (rendered more distinct by the regular vibration of the flowers following the waving of the ground) was in waves about 8 inches long and 1 inch high! I got at this by cross examination and making him first say what he saw, then plotting the wave as he described it (he gave more than double the height I have stated above *at first*), and gradually, by making him come back again to the spot and again plotting the wave, trying to get at the facts. That he *saw* the waves pass along as successive ones he never swerved from!

"The shake was a sharp one and no mistake, but by no means so bad as people supposed at first.

"I necessarily write in haste to catch this mail. You will excuse my not writing before, as I only got your letter a day or two since on my return, and am literally in the midst of a heap of writing and papers—engulfed, in fact.

"Yours, ever sincerely,
"THOMAS OLDHAM."

Amongst the several points of scientific interest in Dr. Oldham's communication we may single out for some remarks :—the mechanism of the production of those great earth-fissures which he so well describes; that of the production of the mud-vomiting fissures or holes, also described; and the reiterated noises heard at intervals after the shock, but not themselves attended by sensible movements.

In all the older earthquake narratives the formation of earth-fissures, large or small, and whether through rock or less coherent material, is, so far as it is intelligibly attributed to any particular play of dynamic forces, set down to be the direct result of the passage of the shock.

The shock was felt to be some sort of undulatory movement of the ground; and the conclusion is jumped to that the ground heaved into curved billows, translated from point to point of its surface, and giving place to others, with short intervals between, like the surface of the stormy ocean, or like that of a carpet shaken upon air (as John Mitchel, of Cambridge, described it); the earth's substance, being *stretched* beyond its limits of extension or cohesion, was thus bent into the convex curve of the terrestrial billow; and so the *rent* or fissure opened; and this closed again as the surface retracted in falling back to the level or below it into the trough between two of these billows.

This is the crude notion of the *direct* production of earthquake-*rents* or fissures, which, with as little of inquiry as of hesitation, has been handed down from book to book of even some of the leaders of geology, and may still be found in some such works of very recent date. The reception of this notion through the senses it was that produced the marvellous tale of the great earthquake at Kingston, Jamaica, of 1692, when, if we believe the narratives, such fissures, suddenly opening across the streets, swallowed up people and cast them out again, or *bit them in two* as they closed again.

It is the foundation too of the hazy yet most exaggerated accounts given by the Royal Commissioners in their report upon the great Calabrian earthquake of the last century (1783), in which the *voragines*, as they call these fissures, and the "mud-eruptions" coming from them, play a part equally marvellous and unintelligible.

The writer was himself the first to announce his conviction, based* on the necessary consequences of knowing the true nature of the earthquake wave-movement, that any direct production of earth-rents or fissures by the movement of the wave-particle or by the transit of the wave was physically impossible, and that their occurrence must be otherwise accounted for (first "Report on the Facts of Earthquakes," Brit. Assoc. Reports, 1850). It was not, however, until after he had been enabled to examine minutely the circumstances and adjuncts of such fissures, both small and large, produced in the great Neapolitan earthquake of 1857, that he was able positively to sustain his previsions by comparison with the facts in nature. The conclusions at which he arrived do not appear, however, to have struck geologists universally with sufficient force to put an end to the old and no longer tenable notion which still disfigures unchallenged the pages of some systematic works.

And as a misconception as to this matter is almost tantamount to having no clear notion at all of the true nature of earthquake-movement, Dr. Oldham's observations are of special importance, the fissures in this case being of first-class magnitude and having concomitants of a very instructive character, while the *modus operandi* of their production once grasped can never again be misunderstood.

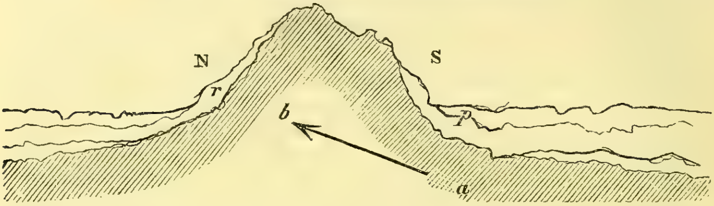
For the more complete statement of the conditions of production of earthquake fissures and of certain of the phenomena which may attend their production, such as the fire and smoke supposed occasionally to ascend from them, the welling up from them of water or mud &c., the writer may refer to his first "Report on the Facts of Earthquakes," §§ 4, 5, and 6, *et passim* (Brit. Assoc. Reports, 1850), and to his 'Report on the Neapolitan Earthquake,' vol. ii., and will here confine himself to calling the recollection of the Fellows present to the leading facts of the case. The production of every earth-fissure by earthquake-shock is only a case of more or less complete landslip, *induced* by the circumstances of the shock; and it is the necessary condition of the production of a fissure thus brought about that, of the earth-masses at either side of the fissure when formed, one or other shall have been, *relatively to the other, free in one direction*—and generally that the mass moved which gives

* It is upon the same radically incorrect conception that the notions of the Messrs. Rogers as to the production of the Appalachian chains of mountains are based—when they attribute their *wave-like* form of transverse section to the translation of great earth-billows petrified, as it were, in their course.—R. M., July 4, 1872.

rise to the fissure shall have been previously in a state not very far removed from one of static instability.

Thus, for example, if fig. 2 represent a transverse section of a mountain-line on both flanks of which incoherent formations (*i. e.*

Fig. 2.—*Ideal Section of Mountain.*



clays, gravels, sands, &c.) repose, and a shock transverse to the anticlinal axis be transmitted through the whole in the general direction *a* to *b*, the effect of the wave of shock in its transit through the entire mass will be, at the arrival side S, to cause the incoherent beds *p* lying on the inclined flank to *slip* downward *during the first semiphase* of motion of the wave-particle.

Actual slippage must occur to a greater or less extent whenever the energy of the impressed movement upon the mass of *p* is equal to or greater than the resistance due to friction of the mass against its own inclined bed, or of its own materials against each other in the plane of the angle of their repose, usually denominated ϕ by writers on mechanics. During the same first semiphase the incoherent masses *r* reposing on the flank N are pressed more firmly against their inclined beds; but the instant after the wave-particle has attained its maximum velocity, and so the second semiphase (or reverse movement of the oscillation) commences, the ordinary pressure of these masses perpendicular to their beds (due to gravity) is more or less reduced, the masses themselves, to which forward motion in the direction *a* to *b* had been previously given, tending now to be left behind. And as their equilibrium *in situ* depends upon their coefficients of friction, either internal or upon their beds, and the effect of these is greater as the pressure on the bed is greater, so the tendency to *slip* is now induced on all the masses at the side N through the momentary reduction of their pressure upon their beds.

Thus the conditions for slip are *first* produced on that side of the chain from which the wave of shock travels, and afterwards on that side towards which its transit is directed. In the second semiphase the tendency to slip in the beds *p* is diminished, as the movement of the wave-particle (now from *b* to *a*) tends to force them *up* their inclined beds.

The fissures, if produced, may be only inceptive, and the slip be limited to the direction transverse to the wave-motion nearly; or the slip, once begun, may assume all the magnitude of great landslips.

In either case, and at both sides of the chain, the general direction of the fissures, if produced, will tend to one transverse to the wave-path and to parallelism with the anticlinal axis; but their actual directions may vary to almost any extent, dependent on the configuration of the rocky beds on which the masses *p* and *r* reposed, and on the intestine motions of the masses themselves, dependent on variable depth, nature of material, wetness or dryness, &c. &c.

The surface of the fissure formed is in such direction as fulfils the law of least action, *i. e.* in that of least resistance of the mass fissured. This surface is almost always curved, usually of double curvature, and conforms commonly more or less to the external contour of the mass before motion was given to it, and to that of the unmoved bed on which it was moved.

These were the conditions of the chief part of the earth-fissures examined by the writer after the Neapolitan shock of 1857, of most of those of the Calabrian one of 1783, and generally of most earthquakes giving rise to fissures at all.

But earth-fissures may also be produced in masses which do not repose on inclined beds, but rest upon an almost, or quite, level surface, as in the case of this Cachar earthquake.

Here the same general dynamic relations as the preceding come into play, though in a rather different manner; and the essential condition still is that the fissured mass must have had unequal support at opposite sides of the plane of the fissure formed.

Whatever may be the nature of the originating impulse generating an earthquake-wave, its actual energy is employed mainly in compressing the particles of the masses immediately surrounding the centre of impulse, which, in virtue of their elasticity, transmit the wave-motion (neglecting transversal vibrations) outwards or onwards, through the surrounding masses, the volume in wave-motion at any instant, *i. e.* the total volume of the particles approaching each other up to the point of maximum condensation and receding from each other to the point of quiescence, being constant.

With the relation of this volume to the originating impulse, the rate of translation of the wave, the maximum velocity of the wave-particle, or the condition of decay or extinction of the wave, we are not now concerned.

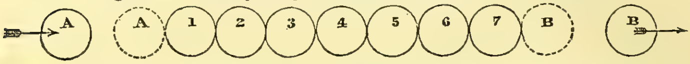
At any point, however, in its transit the work or energy in the wave is being expended in forcing new particles in advance into wave-motion, as those in the rear give up their own motion and return to rest; and were the medium perfectly elastic and of infinite dimensions, such transmitted motion would go on for ever.

The resistance to the energy in the wave, however, is afforded at any instant by the yet undisturbed particles in advance of it; and if these suddenly cease to exist, that is to say, if the elastic medium suddenly terminates, the energy in the wave is unresisted in advance of it, and must be otherwise expended.

Under the actual circumstances of the imperfectly elastic solids with which we are acquainted, it is expended by throwing off, or tending to throw off, a layer or superficial stratum of the mass through which the wave has passed from the terminal surface from which it chiefly emerges: there is also at this surface generated a reflected wave returning into the mass in the reverse direction; but with that we are not here very much concerned.

This is rendered evident to the senses by the analogous movements of a line of billiard balls (fig. 3). When a line of such equal balls

Fig. 3.—*Transfer of Elastic Wave in Ivory Balls.*



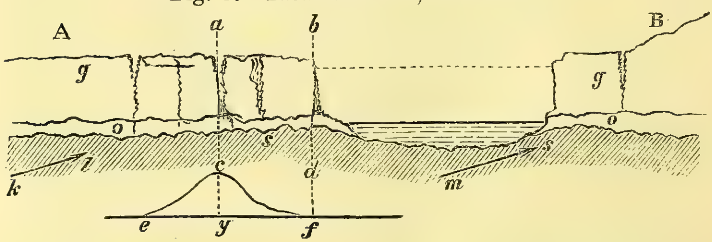
in close contact, 1, 2, 3, 4, 5, 6, 7, B, is struck by a ball A moving *in directum* with the line, each elastic ball in succession from A and 1 to 7 and B is deformed by the blow, and in regaining form transmits the elastic wave from ball to ball. All the balls, 1 to 7, however, remain at rest in space, the transmitted energy being equilibrated between each pair in succession; but the last ball B is thrown off from its contact with 7.

Now, if the balls were all adherent to each other at their points of contact, instead of being free and merely touching, the same result would follow, provided the energy transmitted from 7 to B were sufficient not only to move it off but to overcome the *adhesion*. And this would be equally true if the whole line from 1 to B had been a solid cylindrical or prismatic bar of elastic material, provided that the energy of any impulse delivered by a blow into the bar and compressing it at the end 1, were sufficient to overcome the *cohesion* of the elastic material in some cross section through the point of contact of 7 and B, or nearer to the extremity at B, the bar being thus torn asunder and its extremity thrown forward by the otherwise unbalanced energy of the wave accumulated there.

Now this illustrates in a common-sense way what actually happens when an earthquake-wave having a nearly horizontal wave-path or an emergent one through an extended horizontal mass, such as the Cachar clay-beds, suddenly arrives at an abrupt termination of the mass by their ending in a vertical or nearly vertical cliff, such as that forming the river-banks described by Dr. Oldham.

Thus, let fig. 4 be an ideal section of the river-bed, with the low-water and wet-season water-levels shown; *g* the masses of clay

Fig. 4.—*Ideal Section of River-bed.*



resting upon the ooze-bed *o*, and this on subjacent incoherent strata *s*; and let the wave-path of shock be in the direction *k* to *l* and of *m* to *s*.

At the side A the wave-energy is transmitted from particle to particle through the clays and all beneath, until it arrives at the termination of the mass by the steep river-cliff at *b*; and there it is expended (or part of it) in breaking through the bed of clay at *a*, and throwing off more or less the mass *a b* towards the river. This, resting on its bed of unstable ooze, not only slides forward towards B, but, as it compresses the ooze-bed unequally and the mass of the ooze-bed *itself* is forced forward in like manner but unequally, descends also, and, dependent on many accidental conditions of the adhesion of the surfaces of fissure, the shape of the mass detached, the direction more or less curved of the fissure itself, and many more existing in nature, may tend to turn over likewise, and so descend unequally, and thus when come to next may have no longer a level top, as seen in several of the photographs.

For though the throwing-off force must always act in the line of the wave-path and through the centre of gravity of the detached mass, the resultant of all the retaining forces, whether of support or of cohesion, that kept it in its place may not pass through that same point nor be in the direction opposite to that of the wave-path; so that rotation either in a vertical, inclined, or horizontal plane, or in all, may take place in the movement of the mass before coming to rest. Several fissures, more or less parallel, will nearly always be formed, for reasons that we need not stop to detail; but the place of the great separating fissure *a*, or where the whole of the nearly parallel fissures will most closely congregate, will be at a distance back from the edge of the cliff *b*, about equal to *c d*—that is to say, at about half the amplitude of the material in elastic wave-motion at the same instant, as *e f* in the diagram, wherein the ordinate *e f* represents the amplitude, and the vertical abscissæ the velocities of the wave-particle, increasing in the first semiphase *e y* up to the maximum *y c*, and then diminishing to zero in the second semiphase *y f*, the fissure being formed and the mass being thrown off in most cases just at the instant when, and at the point where, the wave-particle had its maximum velocity. In this diagram the wave-path is taken as normal to the face of the river-cliff; but, as is obvious, it may meet that at any angle at different places of the winding river; and new conditions of fracture and of dislocation of the severed masses will then arise, often producing phenomena of great perplexity to the eye, but into which we cannot here afford space to enter.

A large *portion* of the elastic wave of shock which affected the masses above the level of the river-bed, is thus at the side A superficially extinguished. But the earthquake-wave exists far below this; and so a large portion is transmitted beneath the river-bed in the wave-path *m* to the masses at the side B.

These are shaken, whether directly or not is dependent on questions of relative levels &c., but chiefly through the wave-movement of the subjacent strata; and thus fissures and dislodged masses may, and generally must, occur at *g* also.

Thus, from whichever side of the river the shock comes, or in whatever direction (unless parallel) it meets the river-banks, fissures may be formed, though the direction of these, their extent, the size of masses dislodged, &c. must vary much as these conditions alter.

All that has been thus explained might have been given much more elegantly, succinctly, and accurately by the use of dynamic formulæ, but, probably, not so satisfactorily to many geologists as in the way the writer has endeavoured to put it.

An inspection of Dr. Oldham's photographs will sufficiently indicate the prodigious scale on which these forces may act; and the physical geologist will readily deduce for himself the consequential effects of these huge dislocated masses of mud when thus prepared for the erosive and transporting action of a great tropical river.

It remains to make a few remarks upon the so-called mud eruptions, and upon the inverted sand cones, formed in holes through which such mud, sand, and water have issued.

If the explanations that have already been given as to the displacement of solids by the passage of the shock be applied to the case of a bed of semiliquid ooze, or to any water-bearing bed of gravel or sand supposed horizontal, and the wave-path also very nearly horizontal, it will be obvious that the elastic wave must tend to pack up the water contained in the bed during the first semiphase, and, where an aperture from the water-bed to the surface exists, may cause the level of the water in this to rise, or even momentarily to overflow, or to spout up above the surface, so that neighbouring wells of a shallow class thus alter their levels, or overflow; and the level of the fluid once raised may take some time to subside.

Where the water-bearing bed or that of semiliquid ooze is still nearly level, or the wave-path (as is generally the case) is an emergent one, the last conditions still come into play; but others are now added.

Just as it was explained, that the masses *r*, on the sloping flank N, (fig. 2) are, in the first semiphase of the wave, pressed more firmly against their rocky beds, so the heavy masses of clay (of the Cachar shock) reposing horizontally upon the nearly level bed of ooze beneath, are during the first semiphase pressed downwards upon the latter.

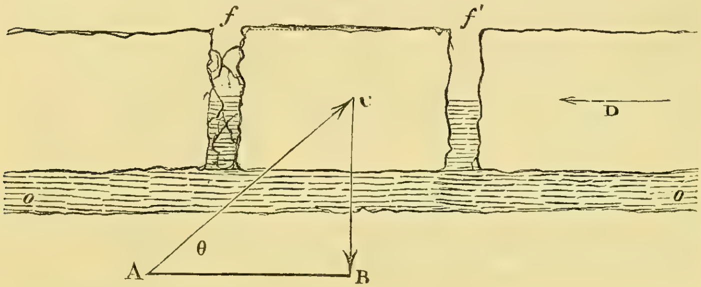
The amount of this pressure for the moment is enormous; for it is the same as would have sufficed to raise the whole mass of the superincumbent clay affected by shock through a height equal to the wave's semiamplitude, and with a velocity equal at least to the mean velocity of its wave-particle resolved in the vertical.

Thus, for the moment, the ooze or water-bearing bed is squeezed like a layer of saturated sponge between the beds below and the clay masses above, by a force far in excess of the ordinary statical pressure due to the weight of the latter. Wherever there may be a sufficiently weak point in the clay-masses, or a well dug through them, or the clay may pass into incoherent sand, the semiliquid ooze, or the water in it, will start up, and may reach the surface under this momentary pressure.

And where apertures are provided (at the same moment almost) by the earth-fissures, the rising liquids will, through these, find easy vent.

As respects the height in the fissures $f f'$ to which the water of the water-bearing or ooze-bed *o o* can rise when the mass C is

Fig. 5.—*Diagram illustrating the Rise of Water in the Fissures.*



pressed down upon it by the vertical component of the wave-motion, if V = the maximum velocity of the wave-particle, which is *in the contrary direction*, impressed upon the mass C, whose weight is = W, then the impressed work accumulated in C is

$$U = \tfrac{1}{2} \frac{W}{g} V^2;$$

and as the mass C is not free to move in the direction B A, the horizontal component of the wave's motion, whose wave-path is A B, makes the angle θ with the horizon; *i. e.* θ is its "angle of emergence."

Then, in the vertical, the impressed work is

$$U = \tfrac{1}{2} \frac{W}{g} \times (V \sin \theta)^2;$$

but

$$(V \sin \theta)^2 = 2 g h, \text{ or } h = \tfrac{1}{2} \frac{V^2}{g},$$

h being the height due to the velocity in the vertical.

Hence the *minimum* height to which the water from the ooze-bed *o o* will be raised by the depression of the mass C is $= h$ in feet, provided there is enough water in the ooze-bed, and that the latter is easily compressible.

This is on the assumption that the specific gravity of the mass C is the same as that of water; but as dense earth is about sp. gr. 1·92, so the actual minimum height of water-rise in the fissure f' will be

$$1{\cdot}92\, h.$$

We have no information as to either the wave-velocity or the angle of emergence for any locality in this Cachar earthquake. If, however, we assume the velocity in the vertical component to be 30 feet per second (or about double that of the great Neapolitan earthquake of 1857), then

$$h = \tfrac{1}{2}\,\frac{900}{32} = \frac{28{\cdot}1}{2}\ \text{ft., and}$$

$$1{\cdot}92 \times 14{\cdot}06 = 26{\cdot}99\ \text{feet};$$

so that it would readily rise above, and flow over the surface of the great clay-bed through the fissures therein, assuming that to be from 30 to 40 feet thick. If any severed mass of the clay-bed, as C, be free to move laterally upon the ooze-bed towards the adjoining one, it is obvious that the water already raised in the fissure f' by the movement impressed in the first semiphase of the wave, may be squeezed up by the approach of D and C, and flow out over the surface of both.

These calculations are of course but approximations, as it is impossible to take into account the resistances which the water in the ooze-bed may oppose to being squeezed out from the solid matter of that bed, or the resistance which may be opposed to its rise in the fissures by their form, clogging with sand or silt &c.

The squeeze thus almost simultaneously given over a vast area of the ooze- or water-bearing bed, though momentary (*i. e.* lasting usually but for a very few seconds), sets a vast body of water in motion; and the work accumulated therein is not instantly lost, but has to be gradually expended. It is therefore expended in causing the forced-up liquids to rise *beyond* the level due to the hydrostatic head, which measures the impressed force, whence the liquid may slowly recede; or if the forces engaged be sufficient to raise the liquid column above the earth's surface, it will continue then to overflow for a longer or shorter time. When this overflow ceases, the last portions of the elevated liquid sink back (unless evaporated) through the apertures whence they rose. Should the liquid forced up be sandy ooze, the sand is carried up in suspension along with the water; and as the volume of the flow slackens, more and more sand accumulates in the aperture of ascent as the water-current gets enfeebled and is no longer able to wash it clean out to the surface; and in the end, the aperture is left nearly full of sand, down through which the last of the water sinks back, as through an imperfect filter-bed; and thus, by the ascending current, at first rapid, then getting slower, ceasing, and then retreating partly or wholly through it, the upper surface of the sand in the aperture gets modified in its form. And should the aperture approach in section to a circular tube or well-shaped fissure, this form tends finally to assume more or less that of a tundish or inverted cone of sand, often washed quite clean from other matter. In a long fissure, several such funnel-shaped cavities may form from point to point.

Should the water-bearing bed be wholly or in part of slimy but tenacious mud, the mud itself may rise and overflow the surface, as it appears to have done in some of the fissures in this Cachar case, and may remain, as it drains and consolidates, in permanent masses above the surface-level, or it may retreat more or less below that;

and if water be carried up before it, or separate from the precipitating mud itself, or rain fill the mouth of the aperture, ponds or wells of water, putrid or black, may remain more or less permanently, as was the case in the great Calabrian earthquake, in the plain of Rosarno, which reposes on a bed of tenacious water-soaked clay.

That the accidental conditions under which this general play of forces may act may be greatly varied, and so give rise to many strange and interesting phenomena, is obvious; and that when gases are extricated by the sudden alteration of pressure upon ooze containing much organic matter still in course of chemical change, splutterings of mud, sand, water, and gases may be ejected together, and present to the uninstructed eye the appearance of a sort of volcanic eruption without fire, is equally obvious.

And where the production of these fissures, and the pressing up of muddy liquid, sand, and so forth occurs upon the vast scale of the Cachar shock, and especially in a tropical climate, many very strange meteorological phenomena may present themselves at and above the fissures, deceptive to the uninstructed eye, and the careful observation and analysis of which must be of great interest to the physicist; upon these, however, the writer must not dwell.

Nor, at the conclusion of a paper perhaps already too long, can he venture to enlarge adequately upon what he believes to be the origin of those recurrent noises, like those of distant artillery firing, mixed with rumbling or rattling noises, which have been observed in this Cachar and many other earthquakes, at shorter or longer intervals after the shock.

The writer believes these to be produced either by repeated falls of rock upon rock in subterranean cavities, temporarily produced or preexistent, or to the sudden giving way by crushing of rock, or to the sudden giving way, by sliding, of one mass upon another under steadily increasing lateral or other pressure, such changes of internal pressure in the more rigid masses of the earth's crust, as well as the less coherent ones, always constituting part of the machinery by which earthquakes are brought about. Such changes of pressure beneath the surface taking more or less long time to readjust themselves into normal equilibrium, those sudden movements, accompanied by the noises of fractures, falls, or grinding of surfaces, may continue, and at more or less regularly recurring intervals, for a considerable time after the shock, or they may precede it for months, as at East Haddam, and in Scotland and Switzerland, or may closely accompany the actual shock itself.

Dr. Oldham's remarks as to the curious statements made to him by an educated native, of what he fancied he had observed of the transit of the earthquake across his garden, afford a good lesson to all engaged in the systematic observation of such phenomena, not to trust to statements of supposed facts made by unpractised observers, however desirous these may be of only stating what they believe to be the truth.

Discussion.

Sir Henry James inquired whether there was any trace of fissuring in the lower beds beneath the slimy ooze.

Mr. Scott wished to ascertain the author's opinion as to the possibility of predicting earthquakes on meteorological grounds, as had been done by M. Bulard, of Algiers, several of whose prophecies were said to have been fulfilled (*vide* 'Comptes Rendus,' March 11, 1872).

Mr. D. Forbes gave some details of the earthquake of Mendoza, a town situated on the vast alluvial plain at the foot of the Andes, in which the phenomena remarkably coincided with those detailed by Dr. Oldham. In that case also he found that the rumours as to fire and smoke having been emitted from fissures were entirely without foundation, the presumed smoke having been nothing but dust. The earthquake was felt over a distance of 1200 miles; and wherever the firm rock came to the surface there was no trace of fissure. But in the plain at the foot of the Andes, consisting of alluvial soil, the deep ground was in parts fissured, and in one place the surface completely furrowed and the turf turned over. He had witnessed numerous earthquakes, and in some cases had been in deep mines during their occurrence; the sound only could be heard, and he could testify to their effects being confined to the surface. The direction of the fissures was invariably at right angles to the line of shock. In South America all the earthquakes could be traced to volcanic centres.

The President inquired as to the distinction to be drawn between the primary and secondary effects of earthquakes, and whether the author thought that no fissures were attributable to the direct action of earthquakes. As to the cause of the sound, like that of a cart carrying iron bars or of an artillery waggon, he wished for further information.

Mr. Mallet, in reply, explained that fissures only take place where masses were comparatively free in one direction. They might extend to enormous depths, though they often closed in rapidly. With regard to the power of predicting earthquakes, he disbelieved in it wholly, and considered that any fulfilment of such prophecies must be due to accident; earthquakes are so numerous, that the chances of such fulfilments are great. The blow or impulse originating earthquakes could not be attributed solely to one cause. It arose often from deep subterranean volcanic action; but it also—especially in the case of long-continued tremors, like those of Comrie or Pignerol—arose from the breaking up or the grinding over each other of rocky beds at a great depth, through the tangential pressures produced in the earth's crust by secular cooling. The arrested impulse of the fall of the Rosberg in Switzerland produced a sensible earthquake. Fissures in hard rock could not be produced *directly* by the shock, because the velocity of impulse in such rock greatly exceeded that of the elastic wave-particle. The earth's crust was at present not in a state of tension, but of compression, through secular cooling.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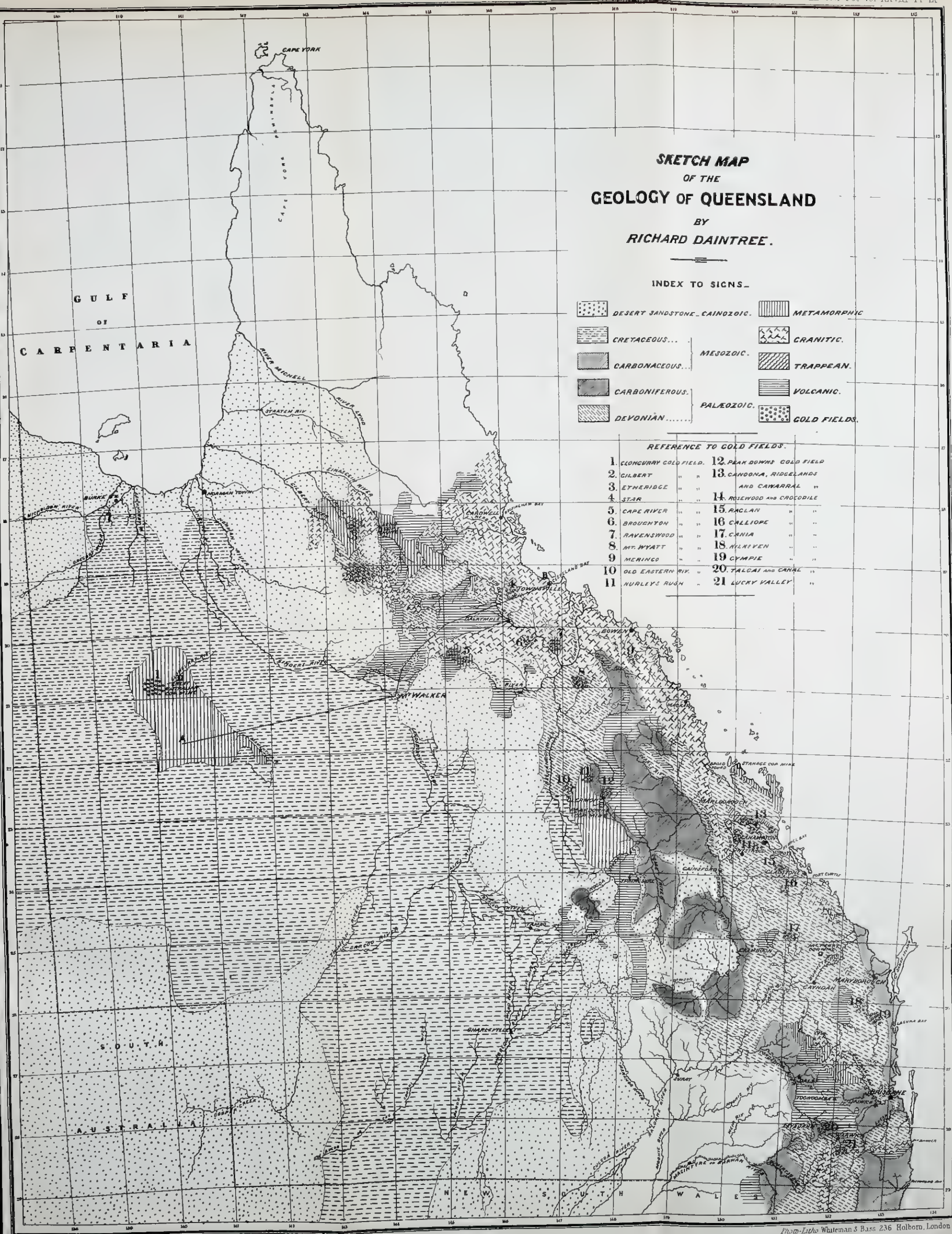
SKETCH MAP
OF THE
GEOLOGY OF QUEENSLAND
BY
RICHARD DAINTREE.
INDEX TO SIGNS_
DESERT SANDSTONE_CAINOZOIC.
CRETACEOUS...
CARBONACEOUS...
MESOZOIC.
CARBONIFEROUS.
DEVONIAN.......
PALÆOZOIC.
METAMORPHIC
GRANITIC.
TRAPPEAN.
VOLCANIC.
GOLD FIELDS.
REFERENCE TO GOLD FIELDS.
1. CLONCURRY GOLD FIELD.
2. GILBERT " "
3. ETHERIDGE " "
4. STAR " "
5. CAPE RIVER " "
6. BROUGHTON " "
7. RAVENSWOOD " "
8. MT. WYATT " "
9 MERINGO " "
10 OLD EASTERN RIV. "
11 HURLEYS RUSH "
12. PEAK DOWNS GOLD FIELD
13. CANOONA, RIDGELANDS AND CAWARRAL "
14. ROSEWOOD AND CROCODILE
15. RAGLAN " "
16 CALLIOPE " "
17. CANIA " "
18. KILKIVEN " "
19 GYMPIE " "
20. TALGAI AND CANAL "
21 LUCKY VALLEY "
GULF OF CARPENTARIA
CAPE YORK
SOUTH AUSTRALIA
NEW SOUTH WALES
BOWEN
MT. WALKER
MARYBOROUGH
BRISBANE

April 24, 1872.

David Johnson, Esq., Grosvenor Road, Wrexham; Edward Harris, Esq., Rydal Villa, Longton Grove, Sydenham; and George Fleetwood Gilfillan Esq., of Klip Drift, Diamond Fields, South Africa, were elected Fellows of the Society.

The following communications were read:—

1. *The following* Extract *from a* Despatch *from H.M. Minister in Teheran.*

(Communicated by the Right Hon. Earl Granville, Secretary of State for Foreign Affairs.)

"The Meshed Agent to Mr. Alison:—

"January 21, 1872.

"On Thursday, the 23rd of December, a severe earthquake occurred at Khabooshan. It destroyed half of the town; about two thousand of the inhabitants were buried under the ruins, and the remainder fled into the plains. On the 6th instant the place was visited with another severe shock, which killed four thousand people and destroyed whatever buildings remained in the place. Four forts adjacent to Khabooshan have so sunk into the earth that not a vestige of them can be traced.

"On the 10th instant Ameer Hossein arrived with two thousand horsemen. They report that about thirty thousand souls were lost by the earthquakes which recently visited Khabooshan, Bojnoord, and the surrounding villages."

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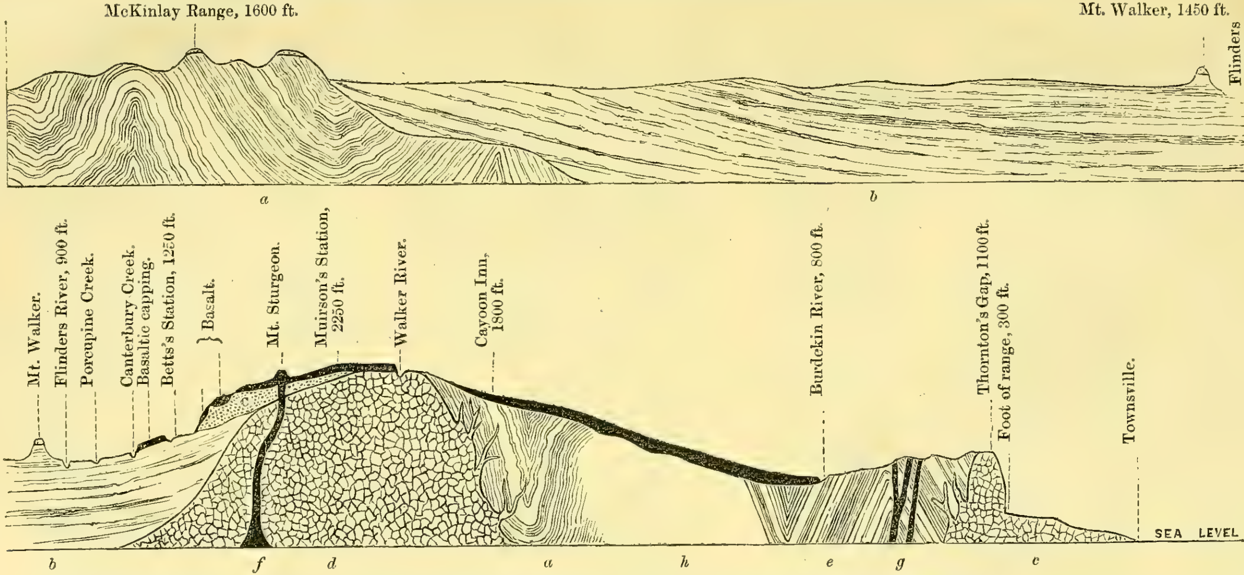
2. *Notes on the* Geology *of the* Colony *of* Queensland. By R. Daintree, Esq., F.G.S. *With an Appendix, containing descriptions of the Fossils*, by R. Etheridge, Esq., F.R.S., F.G.S., Palæontologist to the Geological Survey of Great Britain, and W. Carruthers, Esq., F.R.S., F.G.S., Keeper of the Botanical Department in the British Museum.

[Plates IX.–XXVII.]

The accompanying geological map of Queensland (Pl. IX.) may be accepted as giving the approximate areas and rough outlines of the geological structure and rock-systems developed in that Colony, and is appended for that purpose only. It will necessarily be open to criticism in matters of detail; but the general features of the geological grouping may be relied on. The section (Fig. 1) from Townsville to the Mackinlay range shows all the geological formations in Queensland, north of 20° S. lat.

In a newly settled Colony the first object of the geologist is the determination of those districts in which the best land or available mineral wealth is to be obtained, accuracy in detail and purely scientific investigation being deferred to an often remote future.

Fig. 1.—*Sketch section from Townsville to the McKinlay Range.* (See line on Map.)



a. Metamorphic rocks:—Mica- and Hornblende-Schists, Gneiss, &c., capped in places with Desert Sandstone.

b. Cretaceous:—Grey mudstones, with occasional bands of fine-grained Sandstone and thin layers and concretions of argillaceous limestone. This series forms the watershed separating the waters flowing to the Gulf of Carpentaria from those flowing to the south.

c. Desert Sandstone; also seen capping Mount Walker and some of the summits in the McKinlay range.

d. Granite, Pegmatite, and Felspar Porphyry.

e. Devonian rocks:—Crystalline limestones, clayslates, shales, sandstones, and conglomerates.

f. Volcanic core and point of eruption of basalt.

g. Dykes of intrusive Greenstone.

h. Undetermined rocks, the surface formed by undulating Basaltic downs. Both igneous and sedimentary rocks are exposed in the nearest sections.

I collected the following data whilst prosecuting the search for new gold-fields, on behalf of the Queensland Government, in the northern portion of their territory, as also from the official reports of the Geologist of Southern Queensland, and other trustworthy sources.

The consideration and history of the different formations will be taken in their sequence of time, as far as the stratified or sedimentary rocks are concerned. The igneous rocks will be described under the various groups of Granitic, Trappean, and Volcanic.

Aqueous.
- Alluvial, recent.
- Alluvial, containing extinct faunas.
- Desert Sandstone. *Cainozoic.*
- Cretaceous. }
- Oolitic. } *Mesozoic.*
- Carbonaceous. }
- Carboniferous. }
- Devonian. } *Palæozoic.*
- Silurian? }

Metamorphic.

Alluvial.

Fluviatile or freshwater deposits skirt all the present water-courses; but the accumulations are insignificant on the eastern watershed, except near the embouchures of large rivers, such as the Burdekin, Fitzroy, &c.

On the shores of Carpentaria, however, and in the *south-western* portions of the Colony, where the water-courses have scarcely any fall, and where in seasons of excessive rain the country is nearly all inundated, fluviatile deposits are very extensive.

Although the sediments redeposited as alluvia between the main dividing range and the east coast are, as stated, comparatively insignificant, they represent the denudation of no insignificant amount of varied rock material, since the present physical contour of the eastern portion of the Colony is probably due to the influence of meteoric action, such as rain &c.

Though the dense lavas of the Upper Burdekin (volcanic outbursts of a late Tertiary epoch) are traversed by valleys of erosion, in some cases 200 feet deep and 5 miles broad, yet very narrow and shallow alluvial deposits skirt the immediate margin of the water-courses draining such valleys.

The same conditions are met with in all the more elevated table-lands or ridges which give character to the present physical outline of the eastern main range.

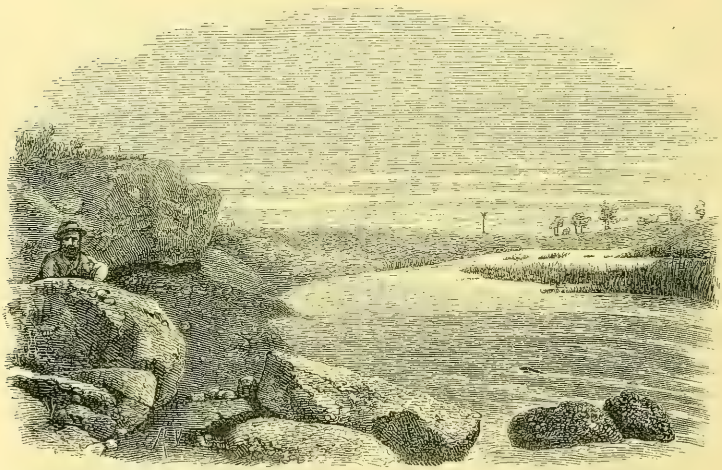
It is only near the mouths of the larger rivers that any extent of alluvium has been deposited; and even these areas are at the present time in seasons of excessive rain liable to inundation, showing that little upheaval of this portion of Australia has taken place since the last volcanic disturbances terminated.

The meteoric or climatal conditions during this period were nearly identical with those of the present time, heavy rains during the summer months causing violent floods, removing seaward the aërial decompositions and denuded materials from year to year.

What lapse of time is represented during this period of erosion is a matter of speculation; but it seems certain that the Mollusca of the present creeks were also the inhabitants of the waters during the whole period of denudation since the last volcanic eruption.

From the Gulf of Carpentaria in the north to Darling Downs in the south, however, the fossil remains of extinct mammalia have been found in breccias and indurated muds, which are representatives of the beds of old water-courses through which the present creeks cut their channels. At Maryvale Creek, in latitude 19° 30′, south, good sections of these old brecciated alluvia occur, a view of one of which is here given (Fig. 2). The fossils from this section, as determined

Fig. 2.—*View of* Diprotodon-*breccias, Maryvale Creek, Northern Queensland.* Lat. 19° 30′ S.



by Professor Owen, are *Diprotodon australis, Macropus titan, Thylacoleo, Phascolomys, Nototherium,* Crocodile teeth, &c.

Imbedded in the same matrix occur several genera of mollusca of species undistinguishable from those inhabiting the Maryvale Creek. My friend and late colleague, Mr. Robert Etheridge, jun., has compared these with the recent forms, and finds them to consist of:—

GASTEROPODA.

Melania pagoda.	Melania, sp.
,, arca.	Limnæa rimosa.
,, subimbricata.	Physa truncata.
,, mœsta.	,, sp.

LAMELLIBRANCHIATA.

Corbicula australis.	Unio, sp.

The fact of these older alluvia forming both the bed and banks of the present water-course (as seen also in the section delineated), goes to prove that *Diprotodon* and its allies inhabited the Queensland valleys when they presented little difference in physical aspect or elevation from that of the present time. The crocodile (*Crocodilus australis*), however, had then a greater range inland than it has now.

A study of these *Diprotodon*-breccias leads to the conclusion that the remains are chiefly entombed in what were the most permanent "water-holes" in seasons of excessive drought, and that the animals came there in a weak and exhausted state to drink and die, just as bullocks do under similar conditions at the present time.

No human bones, flint flakes, or any kind of native weapon have yet been discovered with the extinct mammalia of Queensland.

Cainozoic.

Desert Sandstone.—On the eastern branches of the Upper Flinders river and elsewhere fine sections are exposed of lava resting on horizontal beds of coarse grit and conglomerate, which lie in turn unconformably on olive-coloured and grey shales with interstratified bands and nodules of argillaceous limestone containing fossils of Cretaceous affinities. I have called this upper conglomerate series "Desert Sandstone," from the sandy barren character of its disintegrated soil, which makes the term particularly applicable. Only a few rolled fragments of coniferous wood have been found imbedded in it, proving nothing as to its age; and all that can be asserted is, that its horizon is above and unconformable to the Cretaceous series of the Flinders.

Without doubt it is the most recent, widely spread stratified deposit developed in Queensland. The denudation of the Desert Sandstone since it became dry land has been excessive; but as will be seen by the geological map (Pl. IX.), there still remains a large tract *in situ*, whilst outliers and isolated ridges are to be met with in the most unexpected localities. A view of a cliff section of Desert Sandstone, with outlier, is represented in the accompanying woodcut (Fig. 3).

All the available evidence tends to show that this "Desert Sandstone" did at one time cover nearly, if not quite, the whole of Australia, with the probable exception of the south-eastern corner of the continent from the Cordillera to the ocean. The journals of the two Messrs. Gregory in their expedition on the north-west and north, and Goyder's description of the new settlement of Port Darwin, all bear evidence to the continuity of this so-called "Desert Sandstone" over all the extended areas investigated by them, where denudation has been resisted by local peculiarity of structure or other special causes. Frank Gregory, in his description of the geological peculiarities of that portion of the Nichol Bay country that came under his observation during his exploring expedition of 1861, observes that "it consists of a series of terraces rising inland for nearly 200 miles, more or less broken up by volcanic hills towards the coast.

"The first belt averages from 10 to 40 miles in width from the sea, and is a nearly level plain slightly ascending to the southward with an elevation of from 40 to 100 feet, the soil being generally either light loam or strong clay, according as it is the result of the granite rocks that occasionally protrude above its surface, or of volcanic rocks of black scoria that frequently interrupt the general level.

"Proceeding inland for the next 50 or 60 miles is a granite country that has been originally *capped with horizontal sandstones,*

Fig. 3.—*Cliff and Outlier of "Desert Sandstone" at Cave Creek, Gilbert District, Northern Queensland.*

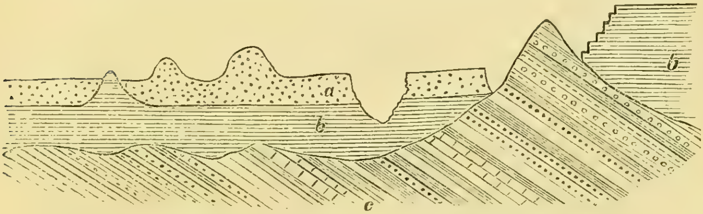
and has an elevation of about 1000 feet; this range terminates to the southward in level plains of good soil, the produce of the next series of more elevated country; whilst towards the northern edges the granite and sandstones have undergone great changes, through the action of numerous trap-dykes, that have greatly disturbed the surface, producing metamorphic rocks, some resembling jasper, and others highly cellular and scoriaceous."

In about latitude 22° on the meridian of Nichol Bay he came upon another and more elevated range trending away to the S.E., having an altitude of 2500 feet above the sea.

This, unlike the last section, has a southern escarpment of 500 or 600 feet, and an average breadth of 8 or 10 miles; it consists of *horizontal sandstones and conglomerates,* which have undergone comparatively little change.

Augustus Gregory's description of the sandstones of the Victoria river, as illustrated by the accompanying section (Fig. 4), agrees with those of the "Desert Sandstone" of Queensland, the specimens from either locality being undistinguishable the one from the other; while the same barren sandy soil, the same hostile *Spinifex*,

Fig. 4.—*Sketch section of the Upper Valley of the Victoria River* (by A. Gregory, Esq., Surveyor-General of Queensland).

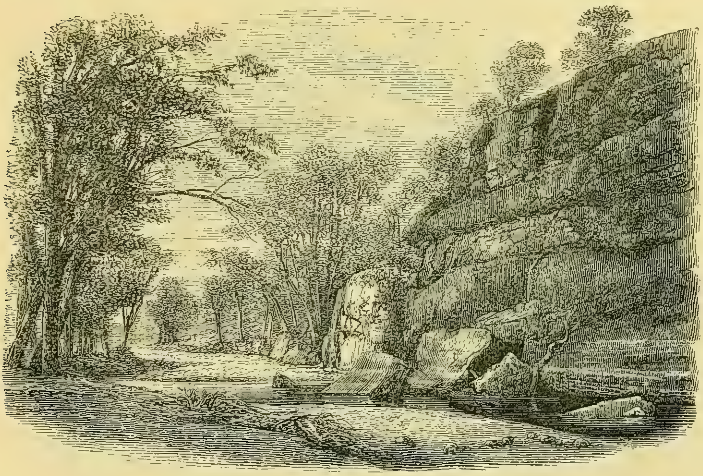


a. Desert Sandstone. *b.* Basalt.
c. Hard sandstones and grey and blue slates (Devonian?).

the same fatal poison-plant, mark its presence from Perth to Cape York.

In Queensland the Upper beds are ferruginous, white and mottled sandy clays, the lower being coarse alternating grits and conglomerates; the extreme observed thickness has not exceeded 400 feet.

Fig. 5.—*Section of "Desert Sandstone," Betts Creek, Northern Queensland.*



A characteristic view of the Upper Desert Sandstone beds is shown in Betts Creek (Fig. 5).

Whether these are marine, lacustrine, or estuarine deposits there is hardly sufficient evidence to show, the enclosed drift wood, as before observed, giving no clue.

A single shell (*Tellina*) found in a bed of horizontal limestone at the head of the Gregory on the Barkly Tableland and forwarded to me by the Rev. W. B. Clarke, of Sydney, would, if belonging to this series, as it probably does, give reason to believe that the lacustrine condition may be eliminated.

What may be the value of this Desert Sandstone for *free* gold is at present unsolved; but the very nature of its deposition seems to preclude the idea that that metal will be found in paying quantities, except where direct local abrasion of a rich auriferous veinstone has furnished the supply.

It is indeed doubtful if any *marine* or *extensive lacustrine* beds, except on their shingle margins, have produced, or are ever likely to produce, remunerative workings of *free* gold, for the simple reason that the majority of the sediments of which they are composed are derived from formations the greater part of which were non-auriferous.

Mesozoic.

Cretaceous.—As early as 1866 a suite of fossils was collected by Messrs. Sutherland and Carson (of Marathon Station) on the Flinders river, and forwarded for determination to Professor M'Coy in Melbourne. They were never figured; but his manuscript names are as follows:—

Reptilia.

Ichthyosaurus australis, *M'Coy*.
Plesiosaurus Sutherlandi, *M'Coy* (allied to that from New Zealand, described by Professor Owen).
Plesiosaurus macrospondylus, *M'Coy*.

Cephalopoda.

Ammonites Sutherlandi, *M'Coy* (resembling *A. Barandieri*, of the Gault of France).
Ammonites Flindersi, *M'Coy* (resembling *A. Beudanti*, Br., of the Lower Chalk of France).
Belemnitella diptycha, *M'Coy* (resembling *B. plena*, of the Lower Cretaceous beds of England).
Ancyloceras Flindersi, *M'Coy* (equalling *A. gigas*, of the Lower Greensand in size, but more nearly resembling in structure the *A. Faborelli* of the Lower Greensand of France).

Lamellibranchiata.

Inoceramus Carsoni, *M'Coy* (resembling the *I. mytiloides*, Sow., of the Chalk of England).
Inoceramus Sutherlandi, *M'Coy* (identical with the English species *I. Cuvieri*).

One locality being assigned to all the fossils alluded to in the above notice, it was evident to me that either fossils from different localities had been mixed together, or derived specimens had been mingled with those obtained *in situ*, and no satisfactory conclusion or inference could be drawn for purposes of correlation with European, Asiatic, American, or African forms. In company with Mr. Sutherland, who supplied M'Coy with the before-mentioned materials, I therefore visited the Upper Flinders, and carefully collected the fossils from three localities, viz. Marathon Station, Hughenden Station, and Hughenden Cattle Station.

At Marathon, which is some forty miles further down the Flinders than Hughenden, there is, close to the homestead, an outcrop of fine-grained yellow sandstone, which has been quarried for building-purposes; and below this, to the edge of a water-hole supplying the house, is a series of sandstones and argillaceous limestones, containing numerous organic remains.

These I have submitted to Mr. Etheridge for examination and correlation, the result of which will appear in the Appendix to my paper; I, however, attach here a summary of the forms determined by him from this locality.

MARATHON.

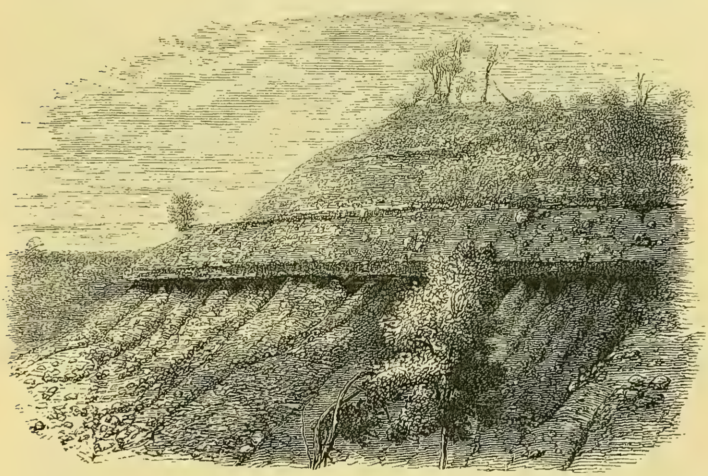
Inoceramus marathonensis, *Eth.* Pl. XXII. fig. 1.
—— allied to problematicus.
—— pernoides, *Eth.* Pl. XXII. fig. 3.
—— multiplicatus, *Stol.*, var. elongatus, *Eth.* Pl. XXII. fig. 2.

From these beds also came M'Coy's Reptilia.

The "Marathon beds," as they may be designated, are undulating, with an uncertain dip. Proceeding from "Marathon" up the Flinders river (most probably over a series of older beds), no cliff-sections are met with; but at Stewart's wash-pool, on the main road, the *Avicula hughendensis*, Eth., of Hughenden is found in abundance.

At Robert Grey's Hughenden Station, however, which lies about three miles east of Mount Walker, a series of calcareo-argillaceous

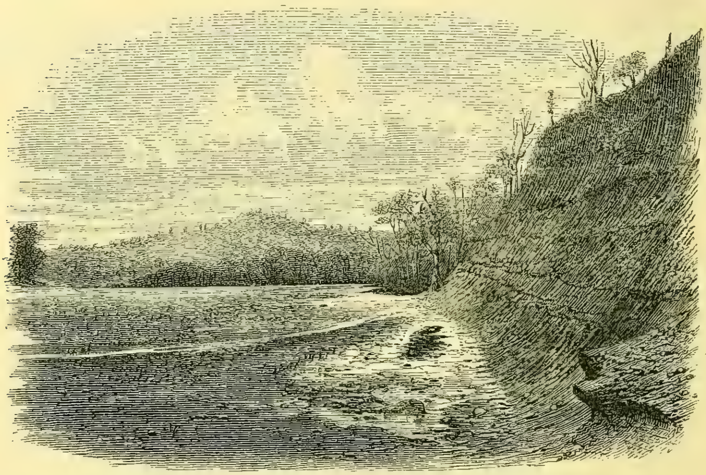
Fig. 6.—*Section of Cretaceous Strata, Betts Creek, Flinders River, Northern Queensland.*



beds crop out, containing a marked and well-preserved fauna, indicating no great difference in *facies* from those of Marathon.

The accompanying section (Fig. 6) of a cliff on Betts Creek, intermediate between Marathon and Hughenden, and one on the bank of the Flinders, about six miles above Hughenden (Fig. 7) shows how nearly horizontal the great Mesozoic system of the Flinders remains;

Fig. 7.—*Section of Cretaceous Strata on the Flinders River, six miles above Hughenden Sheep Station.*



but the latter indicates their gentle dip towards the north-east, and therefore places the Hughenden beds below those of Marathon.

The observations collected on the journey between these two places give the same result.

The palæontological evidence is not sufficient to enable Mr. Etheridge to draw any great line of demarcation.

His determination of the species from the Hughenden beds is as follows:—

Ammonites Beudanti, *D'Orb.*, var. Mitchellii, *Eth.*
—— Daintreei, *Eth.*
Avicula hughendensis, *Eth.*
Pecten &c.

These were obtained from horizontal calcareo-argillaceous beds, fronting the water-hole, where the sheep-wash is placed, about half a mile from the Hughenden Station.

The *Avicula*-bed, which is a very marked band, about 4 inches thick, gives by analysis—

Residue insoluble in HCl, chiefly clay	17·230
Ammonia-precipitate, of which 1·219 per cent. was ferric oxide	9·368
Carbonate of lime	67·888
Carbonate of magnesia	2·520
Undetermined water, &c.	2·994
	100·000

The Hughenden Cattle-station is twenty miles further up the Flinders than the Hughenden Head Station. Here hundreds of

Belemnites are strewn over the surface of the two ridges which front the Cattle-station huts, but they are rarely found in the soft shales which crop out from under an escarpment of "Desert Sandstone."

The lithological character of these Cretaceous strata is such that decomposition is rapid; and cliff-sections are accordingly very rare, the resulting physical aspect being that of vast plains, which form the principal feature of Queensland scenery west of the main dividing range; but that the "Desert Sandstone" has extended over all this country is evidenced by its existence either in the form of outliers, or as a marked feature *in situ* on all main watersheds, or by its pebbles of quartz and conglomerate, which are strewn everywhere over the surface of the plains. The appearance of these vast plains is shown in Fig. 8.

The height of the watershed between the Thompson and Flinders rivers is locally not more than 1400 feet above sea-level; and as

Fig. 8.—*Physical Character of Cretaceous Strata, Flinders River, Western Queensland.*

the former river has to travel as many miles before reaching the sea, it is easy to understand why, in a country subject to heavy tropical rains at one period of the year followed by a long dry season, the river-channels are ill-defined, and vast tracts of country covered by alluvial deposits.

Down the Thompson and its tributaries these Mesozoic rocks are known to extend, though much obscured by flood-drifts. The first to draw attention to the fact was the Rev. W. B. Clarke, F.G.S., of Sydney, who in the year 1867 received a suite of fossils from Wollumbilla Creek and the surrounding district, which he described in

Quart. Journ. Geol. Soc. vol. xxiii. p. 7, suggesting that they were "Rhætic."

A thorough examination of these by Charles Moore, Esq., F.G.S., the results of which were detailed in Quart. Journ. Geol. Soc., vol. xxvi., led him to the conclusion that the Wollumbilla beds have their nearest representatives in the Oxford Clay. But it is possible that fossils from different localities, or perhaps drift specimens, have been mixed up, as he says "it is not easy to decide with certainty as to the exact position of the fossils that come from Wollumbilla. The Lias, the Great Oolite, the Oxford Clay, the Portland Oolite, and the Cretaceous beds may each put in a claim; but that of the Oxford Clay appears to be the strongest."

The Bungeworgari and Amby river-beds are considered by Moore to be Cretaceous. This much then can be asserted, that all the great plains of Queensland westward of the main coast-range consist of subaërially decomposed Oolitic and Cretaceous shales, limestones, and sandstones, or the river-detritus of such, redeposited on their surface.

That this portion of the Mesozoic system extends throughout the whole of Central Queensland to Western Australia is also more than probable, hidden, however, over large areas by "Desert Sandstone."

The finding, by Stuart, of a *Cytherea*? (first mentioned by Clarke) on the Gregory river, a few miles north of Finnis Springs, and the extent of marly plains similar in character to those on the Flinders, the well-known occurrence of Cretaceous fossils in the Moresby ranges, and of Oolitic in other parts of Western Australia, favour this idea. We may look forward to the clearing-up of this point when the collections of the South Australian Telegraph party are described.

The only variety in the lithological character of the Flinders- and Thompson-river Mesozoic rocks, is the change from shale to fine-grained sandstone in the alternating beds, the shale greatly predominating; its line of bedding marked by thin bands and nodular layers of argillaceous limestone.

One other peculiarity in the strata forming the series is the presence at intervals of thin layers of limestone having the well-known cone-in-cone structure.

This has more the appearance of a chemical precipitate than a mechanical deposit, and contains no fossils. Its analysis gave:—

CONE-IN-CONE LIMESTONE.

Insoluble in hydrochloric acid	14·920
Ammonia-precipitate	4·860
Carbonate of lime	75·458
Undetermined constituents	4·762
	100·000

How far the Flinders and Thompson series have extended over the dividing ranges is not yet thoroughly determined.

On Pelican Creek, a tributary of Bowen river, near an out-station hut of Mr. McDougal, a small patch of ferruginous grit caps a single hill-top; and in it numerous specimens of *Panopæa plicata* are found imbedded.

From Gordon Downs, at the head of Roper Creek, the Rev. W. B. Clarke has forwarded me a suite of specimens, which, on Mr. Etheridge's authority, may be referred to the same horizon as the Pelican-Creek beds.

They consist of the following genera:—

Panopæa.	Cucullæa.
Pholadomya.	Homomya*.
Tancredia.	Pleurotomaria*.

Considering these Pelican-Creek and Gordon-Downs strata the representatives of a lower horizon in the Mesozoic series than those of the Flinders river, the direct representatives of the Flinders rocks have as yet been unrecognized to the east of the dividing range. A very large portion of Queensland, however, as far north as 20° S. latitude, between the dividing range and the eastern seaboard, is covered with a series of beds, chiefly freshwater, containing abundance of plant-remains, in the upper portion of which a few beds only contain a fauna which seems, on palæontological evidence, to occupy a position between the Gordon-Downs and Flinders-river series.

These beds crop out at the township of Maryborough, and have been used by the Corporation of that thriving place as quarries for road-metal. The contained shells have been named and arranged by Mr. Etheridge as follows:—

Cyprina expansa, *Eth.* Pl. XIX. fig. 1.	Tellina maricæburiensis, *Eth.* Pl. XX. fig. 6.
Trigonia nasuta, *Eth.* Pl. XIX. fig. 2.	——, sp. Pl. XX. fig. 7.
Cucullæa robusta, *Eth.* Pl. XX. fig. 1.	Panopæa sulcata, *Eth.* Pl. XXI. fig. 2, 2*a*.
—— costata, *Eth.* Pl. XX. fig. 2.	Natica lineata, *Eth.* Pl. XXI. fig. 1.
Nucula gigantea, *Eth.* Pl. XX. fig. 4.	Pulvinites? Pl. XIX. fig. 3.
—— quadrata, *Eth.* Pl. XX. fig. 3.	Cardium? Pl. XIX. fig. 4.
Leda elongata, *Eth.* Pl. XX. fig. 5.	
Avicula alata, *Eth.* Pl. XX. fig. 8.	

Up to the present time, within all the area marked on the map as occupied by Carbonaceous Mesozoic strata, only the Maryborough beds have yielded fossil remains other than plants. On tributaries of the Condamine, Brisbane, and Mary rivers, where numerous coal-seams are known to exist, several of which have been and are now being worked, these plant-remains are of the same character.

A collection from two localities has been examined and named by W. Carruthers, Esq., F.R.S., F.G.S. A suite from the Tivoli coal-mine he finds to consist of:—

Pecopteris Daintreei.	Schizopteris elongata.
—— odontopteroides.	Tæniopteris Daintreei.
Cardiocarpon australe.	—— gracilis.
Cyclopteris cuneata.	—— australis.

* These casts are referred to and figured by Mr. Etheridge in his Appendix.

The Burrum coal-seams, worked for some time on a branch of the Mary river, lie below the Maryborough *Cyprina*-sandstones; and their relation to the Wollumbilla- and Gordon-Downs series has yet to be unravelled.

The idea which seems to offer the greatest amount of feasibility is, that contemporaneous with the deposit of a succession of marine beds to the westward of the dividing range, at a period in time extending through the Oolitic and part of the Cretaceous period, a vast lacustrine deposit was accumulated over a large area to the eastward of the same range, to which the sea obtained access after a very considerable thickness of freshwater beds had been piled up.

Beds of coal are a marked feature in these Mesozoic lacustrine beds, whilst their supposed marine equivalents to the westward are, as far as we have any observations on the subject, entirely devoid of that valuable mineral.

The appearance of these lacustrine coal-measures differs in a very marked manner from their supposed marine representatives to the westward. Coarse grits and thick-bedded sandstones form the majority of the strata, though shales, mudstones, and limestones are interstratified throughout the system.

The physical difference is even more marked; level plains destitute of timber characterize the one, whilst broken ridges, covered in great measure with dense scrub and fine timber, are the attendant features of the other.

It is of great importance to the future of the colony to ascertain if the carbonaceous division of the Mesozoic formation is represented in any portion of the western plains between Wollumbilla and the Upper Flinders. If so, the coal-fields of Queensland would, indeed, be inexhaustible, and a stimulus might thus be given to the construction of that natural trunk-line of railway for Eastern Australia (first suggested by the Hon. J. Grant, late Minister of Lands in Victoria), from the Murray to the Gulf of Carpentaria. The necessity for this will become the more apparent when the rich gold-fields and mineral lodes of Northern Queensland are somewhat more developed, and when these western plains, the richest pasture in Australia, are fully stocked with cattle.

It is hoped that the determination of groups of fossils from the localities here mentioned may form bench-marks, so to speak, for future observers who may work this practically interesting subject to a more definite conclusion; and the leading minds and students of physical science in the colony look with anxiety to the parent societies of England to aid them in their attempts to decipher the structure and past history of this great area, whose yet unrecorded facts must yield only to patient labour.

Mineral Springs.—There is one other subject of practical interest connected with the great western Mesozoic plains; and that is the occurrence of hot alkaline springs, which suggest the possibility of obtaining supplies of water on the Artesian principle over some portion at least of this area.

At Gibson's Cattle-station on the Saxby river, a tributary of the

Flinders, a spring of hot water rises above the surface of the plain; and its overflow deposits a white incrustation, which on analysis by Dr. Flight, under the direction of Professor Maskelyne, afforded:

Water	27·793
Silica	0·600
Chlorine	3·369
Sodium	2·183
Carbonic acid	33·735
Soda	31·690
	99·370

The sulphuric acid, of which there was a small portion, was undetermined.

Apart, therefore, from the 5·552 per cent. of chloride of sodium, the deposit consists of sesquicarbonate of soda, or native "Trona," and as such it is used by the settlers for culinary purposes, &c.

The importance of this evidence as to the probability of finding Artesian supplies of water in districts where such springs are met with, should not be lost sight of; and a bore put down in the vicinity of one of them (for this is not the only one) might, if successful in obtaining water, lead to most important practical results.

Palæozoic.

Carboniferous.—Whilst the affinities of the southern coal-field of Queensland are Mesozoic, a northern field, of even larger extent, has a distinct fauna more resembling the Palæozoic Carboniferous of Europe.

In the upper portion of the series the organic remains are chiefly confined to plants, the most abundant of which is *Glossopteris*, imbedded with less numerous specimens of *Pecopteris*, *Sphenopteris*, &c.

In the lower strata, *Producti*, *Spiriferæ*, &c., of true Carboniferous age, are found associated with the above flora, though the plants are very sparingly represented, and in very imperfect forms.

The Dawson, Comet, M'Kenzie, Isaacs and Bowen rivers drain this Carboniferous area; and numerous outcrops of coal have been observed on these streams. No commercial use, however, has yet been made of any of them, as the measures generally are too far inland to be made available until the railway-system of the country is extended in that direction.

Messrs. R. Etheridge, F.R.S., and W. Carruthers, F.R.S., have examined and named, the one the mollusca &c., the other the plants, from different localities over this large area.

The former describes, from Cracow Creek on the Dawson river:—

Chonetes cracowensis, *Eth.* Pl. XVIII. fig. 2.
Pleurotomaria (?) Pl. XVIII. fig. 3.

From Weelwondongara Creek, Nogoa River:—

Productus or Strophalosia.
Streptorhynchus

From the Head of Roper Creek and from the Bowen River:—

Streptorhynchus Davidsoni, *Eth.* Pl. XVII. fig. 1.
Spirifera striata, *Eth.* Pl. XVII. fig. 5.
—— convoluta, *Eth.* Pl. XVII. fig. 3.
—— allied to bisulcata, *Sow.* Pl. XVII. fig. 4.
Productus Clarkei, *Eth.* Pl. XVII. fig. 2, 2*a*, 2*b*.

From the head of the Don River a suite of fossils has been forwarded by Rev. W. B. Clarke, whom we also have to thank for the specimens from the Nogoa and Dawson rivers.

These are said to overlie the auriferous series there, and consist of:—

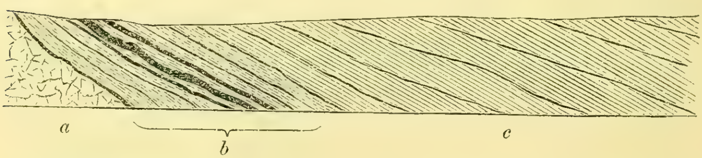
Murchisonia carinata, *Eth.* Pl. XVIII. fig. 5.
Naticopsis (?) harpæformis, *Eth.* Pl. XVIII. fig. 6.
Productus longispinus, *Sow.* Pl. XVIII. fig. 9.
Spirifera allied to striata, *Sow.* Pl. XVIII. fig. 8.
Griffithides dubius, *Eth.* Pl. XVIII. fig. 7.
Strophomena rhomboidalis, *Eth.* Pl. XVIII. fig. 1.

The whole of these forms agree with those found in the Hunter-river series of New South Wales, which there, as in Queensland, are found at the base of the great Palæozoic coal-group of that Colony.

A sketch section of the lowest observed coal-seams, with several hundred feet of *Productus* beds resting on them, is here given (Fig. 9).

This section is observed about half a mile up a creek which joins the Bowen river one mile below the ford at the road crossing from

Fig. 9.—*Sketch section of lowest observed Coal-seams near the Nebo Crossing of Bowen River.*



a. Porphyrite.
b. Freshwater shales &c., with three coal-seams. Fragments of *Glossopteris*, but no marine shells.
c. *Productus*- and *Spirifera*-beds, with abundance of Carboniferous Mollusca.

Bowen to Nebo. The strata are here locally upheaved by the intrusion of the trap range which forms the source of the creek. At the junction of the creek, however, the dip is very slight, although the beds are quite conformable. The marine beds are generally argillaceous limestones, often very ferruginous; whilst the upper beds are coarse grits and sandstones with interstratified shales. In these the impressions of *Glossopteris* are very common and sometimes beautifully preserved; but I have never been able to find the fauna and flora unmistakably represented in the same bed.

The only section that has come under my observation in which

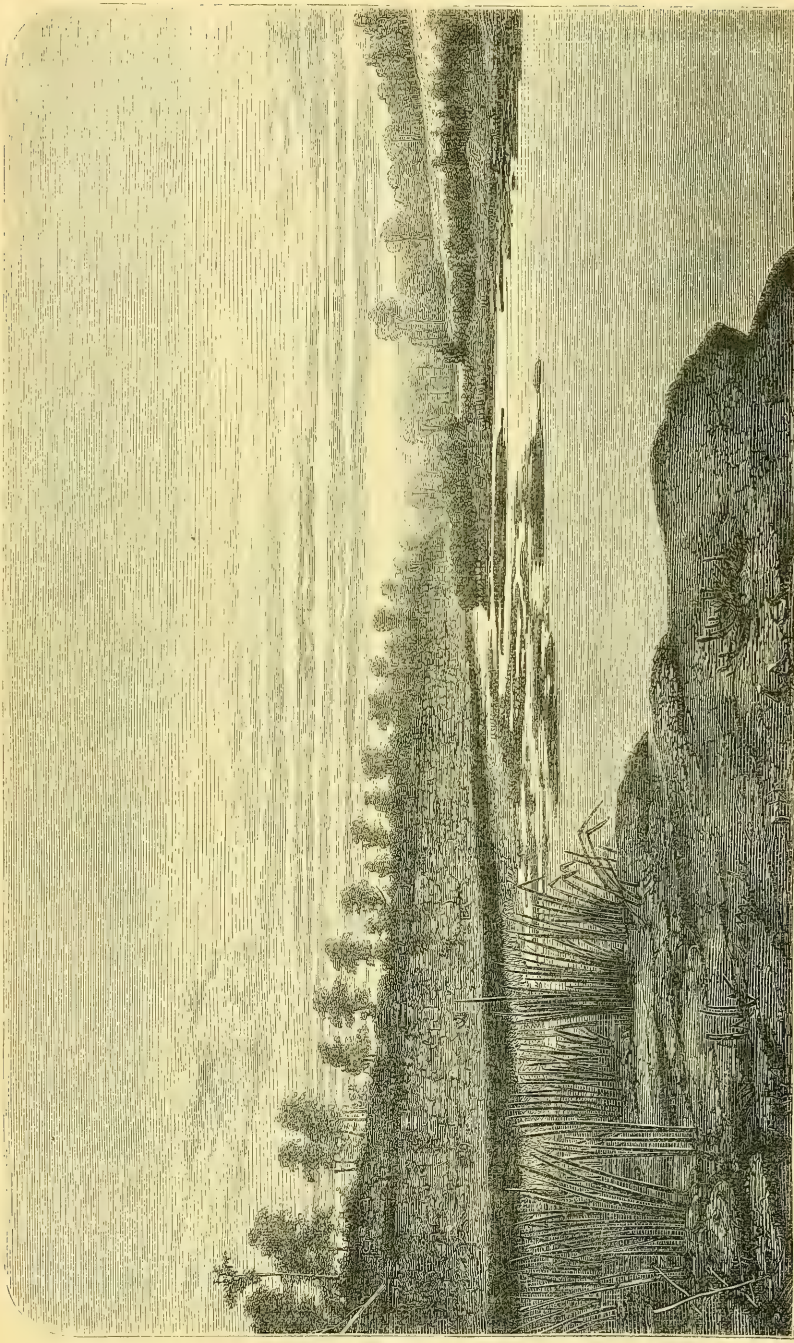


Fig. 10.—*Marine beds resting directly on a Coal-seam, Pelican Creek.*

marine beds are seen to rest directly on a coal-seam was at Pelican Creek, a tributary of the Bowen river, a view of which is here given (Fig. 10). At the base of this cliff a seam of coal about four feet thick crops out the entire length of the section. Directly upon this rests a coarse-grained sandstone, with a few imperfect casts of shells, while at the top of the cliff an arenaceous limestone band holds abundant specimens of the *Streptorhynchus crenistria*, so common throughout all the lower marine series.

No plant-remains could be detected in the section; but (as will be observed in the view) the dip is very slight down the creek; and in the next cliff, on the downward course of the stream, we have a section of the measures of nearly the same dimensions, with shale and sandstone interstratified, in which very perfect impressions of *Glossopteris* were found.

In fact, throughout Australia, as far as observation has yet extended, *Glossopteris* is confined to the older coal-measures, of which the *Producti* and *Spiriferæ* above described are the marine representatives. In Tasmania, New South Wales, and Queensland, at least, this holds good; and where *Glossopteris* occurs, the associated marine fauna is always of Palæozoic type.

In the Tæniopteris *coal-measures of Victoria, Richmond River, New South Wales, and the Southern coal-field of Queensland no* Glossopteris *has yet been found*, and the *Productus*- and *Spirifera*-beds are also absent. It would seem therefore that, apart from the presence of a distinguishing fauna, *Tæniopteris* may be taken as evidence of the Mesozoic, and *Glossopteris* of the Palæozoic coal-formations of Australia.

Devonian.—From the southern boundary of Queensland up to latitude 18° south, a series of slates, sandstones, coral-limestones, and conglomerates extend to a distance of 200 miles inland; these are sometimes overlain by coal-measures, sometimes by volcanic rocks, and consequently do not crop out on the surface over such districts. Their average dip and general character are shown in Fig. 11.

Isolated granitic and metamorphic areas also occur in the same belt of country; these either were islands in the ocean whose accumulated sediments they represent, or have been laid bare by subsequent denudation or intrusion.

North of latitude 18° south, however, over the Cape York Peninsula, this series (so far as we have any evidence) is absent, granites and porphyries capped by "Desert Sandstone" forming the *ranges* on the eastern, and their abraded ingredients, the *sandy tea-tree flats*, those on the western side of that inhospitable tract of country.

Lithologically this very extensive development of Palæozoic rocks agrees with the "Devonian" system of England; and the palæontological evidence is confirmatory of the same idea. In the higher members of this group, which, from their general analogy to the English group of that name, we will term Devonian, specimens of fossil plants are abundantly met with.

W. Carruthers, Esq., F.R.S., has described and named those from three widely separated localities, Mount Wyatt, Canoona, and the Broken River, and refers them all to one form, *Leptophlœum rhombicum*, previously described by Dawson as occurring in the Upper Devonian series of Canada.

At Mount Wyatt the plant-beds are interstratified with strata containing Spirifers &c.; and as these are fully described in the

Fig. 11.—*Section of Devonian Strata, Corporation Quarry, Rockhampton.* (On the left is a dyke of dolerite traversing the Quarry at right angles to the strike of the sedimentary rocks.)

Appendices attached to this paper, no further mention of them is required here.

From various shafts sunk through the "Devonian" rocks of the Gympie mining-district, a well-preserved fauna has been collected.

Mr. Etheridge's determinations of these furnish the following list of species:—

Euomphalus, sp.
Spirifera undifera, var. undulata, *Röm.* Pl. XVI. figs. 3, 4, 5.
—— dubia, *Eth.* Pl. XVI. fig. 6.
—— vespertilio, *Sow.* Pl. XVI. fig. 2.
Edmondia obovata, *Eth.* Pl. XIII. fig. 3.
—— concentrica, *Eth.* Pl. XIII. fig. 2.
Pleurotomaria carinata, *Sow.* Pl. XV. fig. 6.
Aviculopecten multiradiatus, *Eth.* Pl. XIII. fig. 1.
—— limæformis, *Morris.* Pl. XIV. fig. 1.
Ceriopora laxa, *Eth.* Pl. XXV. fig. 2.
Fenestella fossula, *Lonsd.* Pl. XXV. fig. 1.
Strophomena rhomboidalis, var. analoga, *Phill.* Pl. XVIII. fig. 1.

At the Lucky-Valley diggings and at Apis Creek, near the Apis Creek homestead, peculiar casts of encrinital stems, probably belonging to the genus *Actinocrinus*, occur in a lydianized slate. The strike of this bed is in both places about north 30° west, which line would connect the two outcrops, although nearly 300 miles apart.

In the limestone bands which form the lower portion of the series (shown in Fig. 12), corals are very numerous; in fact the limestones,

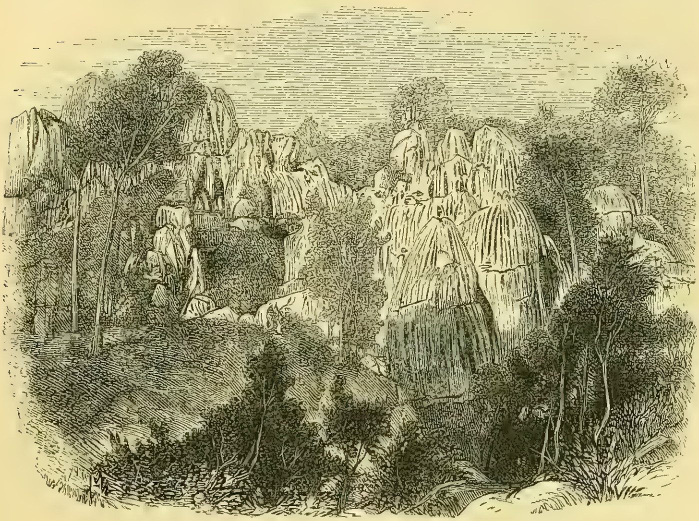
Fig. 12.—*Section of Devonian Coral Limestone, Terrible Creek, near Messrs. Cunningham's Cattle Station, Burdekin River, Northern Queensland.*

where little alteration has taken place, are a mass of aggregated corals; and as this class of rock has resisted aerial destruction better than the associated slates and sandstones, the barriers thus formed mark the trend of the rock-system to which they belong, in a very picturesque and decided manner; their bold, massive and varied outline chiselled into the most delicate fretwork by nature's hand, is relieved by a wealth of richly tinted foliage, unknown in the surrounding bush; and the eye jaded with the monotony of the "eternal Gum-tree" turns with delight to the changing tints and varied scenery presented by these barrier-like records of the past (Fig. 13).

On the Broken River, a tributary of the Clarke, in Northern Queensland, the entire Devonian system, as developed in Queensland, could be easily and satisfactorily mapped. The branches of this river cut right across the strike, and the bare edges of the rocks are often exposed over the intervening ridges from creek to creek. Well-marked beds of interstratified conglomerates seem to retain their character over large areas; and the loose pebbles from these can be followed readily over the ridges, whilst the rocks from which these pebbles are derived crop out in the gullies and ravines.

As a large proportion of them are of quartz, the ridges covered by them are often mistaken by miners for indications of a "deep lead" or old river-course. Though of course this is an error soon discovered, I have been informed that they have often found gold under such

Fig. 13.—*Limestone Barrier, Broken River, Northern Queensland.*



conditions; if so, it would be a very valuable addition to our knowledge of the earliest period at which auriferous quartz veins were formed.

On the track from the Broken River to the Gilbert Diggings, Devonian rocks several thousand feet thick may be observed, as they are continuous in dip, without being repeated, for at least five miles across the strike, with an average inclination of 60°.

Although on the Broken River and its tributaries a breadth of thirty miles, with a length of sixty miles, is occupied by a persistent outcrop of Devonian strata, gold has only been discovered in remunerative quantities in a small gully, heading from a leading ridge, where a trap dyke has penetrated the Palæozoic rocks of the district.

The following districts, however, where Devonian rocks prevail, have been centres of gold-mining enterprise:—

Lucky Valley.	Morinish.
Talgai.	Rosewood.
Gympie.	Mount Wyatt.
Calliope.	Broken River.
Boyne.	Portion of Gilbert.

In every case here cited the country is traversed by trap-rocks of a peculiar character, either diorite, diabase, or porphyrite; and tufaceous representatives of these are also found interstratified in the upper portion of the same formation, and occasionally throughout the other beds.

At Gympie, one of the richest quartz-reefing districts in the colony, the auriferous area is confined to veins traversing a crystalline diorite, or within a certain limit of its boundary, marked by the presence of fossiliferous diabase tufas.

Of the crystalline rock at Gympie Mr. Aplin, who reported on the district, gives the following description:—

"In irregular-shaped masses or broad dykes this rock occurs at intervals over a large portion of the area of this gold-field, but is most prominently developed within a zone half a mile or more in width, having a longitudinal direction of about N. 60° W., and embracing the space from the 'Lady Mary' hill to that on which the Gympie township commences.

"It is in the decomposed upper portions of this rock, which weathers brown and argillaceous, though retaining its compactness, that the quartz veins traversing it are found to be so highly productive.

"In its ordinary condition it is excessively hard, and is the most formidable obstacle the miners have to contend with, some from the very surface, and others at varying but comparatively shallow depths."

Of the lode-stones outside a certain limit from this crystalline rock he says:—"*The quartz-veins associated with the slates or other sedimentary rocks not connected with, or affected by, the greenstone have hitherto been found not to contain gold in paying quantity.*"

Mr. Hacket, who devoted a much longer time to the survey of the Gympie gold-field, confirms Mr. Aplin's opinion on the latter point, as he says in his report:—

"Skirting the greenstone-belt on both sides is a series of siliceous slates and quartzites, highly metamorphosed, and in many cases jasperized, banded, and cleaved.

"In this latter formation no gold has yet been found, although many reefs have been explored."

Mr. Hacket, however, seems to have thought that the crystalline rocks were interstratified with the slates &c.

My own impression, formed from two short visits to this locality, was that the crystalline rock was in all cases intrusive, whilst the so-called "fossiliferous greenstone" was a tufaceous deposit, partly contemporaneous with, partly the result of the denudation of the crystalline rock which represented the core or cores of Devonian trap-vents.

The analysis of the two varieties of rock above mentioned, viz. the so-called Gympie "greenstone" and the "fossiliferous greenstone," gave the following results:—

Gympie Crystalline Diorite (Pl. X. fig. 2).

General Constituents.

	Per cent.
Silica	50·500
Alumina	18·485
Ferric oxide	1·470
Ferrous oxide	6·440
Lime	8·800
Magnesia	8·530
Potash	0·635
Soda	1·655
Sulphur	0·190
Carbonic acid	0·820
Water, constitution	1·600
Water, hygroscopic	0·850
	99·975

Specific gravity, 2·752.

Portion soluble in HCl., 54·775 per cent.

Silica	41·944
Alumina	19·562
Ferric oxide	2·683
Ferrous oxide	7·786
Lime	10·087
Magnesia	9·940
Potash	0·210
Soda	2·000
Carbonic acid	1·400
Sulphur	0·347
Water, constitution	2·921
Water, hygroscopic	1·552
	100·432

Insoluble in hydrochloric acid, 45·225 per cent.

Silica	60·862
Alumina	17·187
Ferrous oxide	5·180
Lime	7·240
Magnesia	6·821
Soda	1·226
Potash	1·028
	99·544

Gympie Fossiliferous Tufa.

Analysis.

	Per cent.
Silica	43·150
Alumina	21·570
Ferric oxide	3·610
Ferrous oxide	8·520
Lime	12·450
Magnesia	1·785
Soda	1·710
Potash	1·310
Carbonic acid	3·560
Water, constitution	1·100
Water, hygroscopic	0·500
	99·265

Insoluble in hydrochloric acid, 45·100 per cent.

Silica	60·753
Alumina	19·395
Ferrous oxide	4·800
Lime	7·206
Magnesia	1·873
Soda	3·791
Potash	2·904
	100·722

Soluble in hydrochloric acid, 54·900 per cent.

Silica	28·234
Alumina	23·442
Ferric oxide	6·575
Ferrous oxide	11·666
Lime	16·074
Magnesia	2·022
Carbonic acid	6·484
Water, constitution	2·003
Water, hygroscopic	0·910
	97·410

Mr. Allport, of Birmingham, has examined sections of these analyzed rocks under the microscope, and thus describes them :—

Of the *crystalline rock* he says :—

"This is a diorite, containing hornblende, triclinic felspar, orthoclase, a little brown mica (biotite) and pyrites.

"Many of the minerals are imperfectly crystallized.

"The crystals of felspar showing bands of colour or striæ, when examined in polarized light, are of course triclinic, whilst those of one colour are probably orthoclase. There are some twins showing two colours sharply divided by the line of junction of the two halves; and these are *certainly* orthoclase.

"The secondary products are a little chlorite, and two or three blebs of quartz, filling spaces between the crystals.

"The rock is not much altered."

Of the *fossiliferous tufa* he says:—

"It is a fragmentary rock, and has undergone so much alteration that the constituents cannot be well identified. There are, however, some grains of augite and magnetite. The fragments are imbedded in a chloritic base, which is itself a product of alteration."

Of another specimen of the same character from the *West-coast Reef*, Gympie, he remarks:—

"This is a characteristic trappean ash or breccia; it consists of numerous fragments of rather fine-grained trap-rocks, broken crystals of felspar and augite, many black grains of magnetite, and fragments of other rocks, the whole forming a compact mass in which there is now much chlorite."

The analysis of the crystalline rock indicates no very determinate results, but suggests the presence of two felspars and two varieties of hornblende, with a little chlorite, carbonate of lime, and pyrites.

The insoluble portion may be a mixture of perthite and an insoluble aluminous hornblende, whilst the soluble portion indicates a mixture of oligoclase, an iron and magnesian hornblende, like pargasite, and a smaller proportion of a chloritic mineral, as indicated by the water of constitution.

The absence of augite in its composition would, notwithstanding the presence of the products of decomposition, chlorite and carbonate of lime, place it among the diorites. The so-called fossiliferous greenstone, however, would perhaps be most correctly called a "diabase tufa," as shown both by analysis and microscopic examination.

Whatever may be the proper technical term for the class of rock of which the Gympie crystalline diorite is a typical example, the fact remains that throughout the whole extent of the great Devonian area of Queensland no portion has yet been found to include auriferous veinstones which will pay to work, where trappean disturbance of this character is not present.

At the Boyne the Devonian slates are cut at various angles by dykes of hard crystalline diorite; and for the most part the auriferous quartz-veins are found at the absolute intersection of the two. The very intelligent manager of the Boyne Company's leased ground had found this fact verified in all the mining operations conducted there.

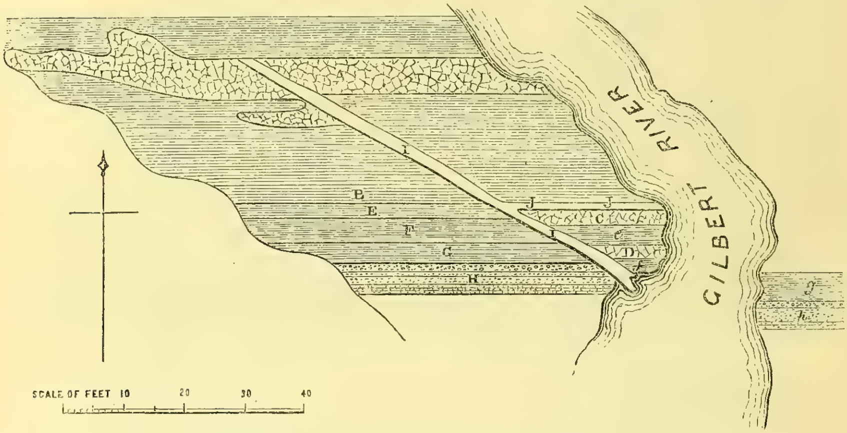
At Calliope intersecting dykes of serpentine, or diorite, are the surest guides to the richest vein-stones, the Devonian slates and limestones being the rocks intersected.

At Crocodile, Blackfellows, and Morinish diggings, in the Rockhampton district, the conditions are analogous to those of the Boyne, Calliope, and Gympie,—the best reefs lying at or near the junction of the diorite and the Devonian "country."

In fact it would be only a repetition to describe the mode of occurrence of the gold at Lucky Valley, Talgai, Rosewood, Mount Wyatt, the Broken River, and the western portion of the Gilbert diggings, so nearly identical is it with those above mentioned.

The ground-plan of a portion of bare rock exposed in the bed of

Fig. 14.—*Ground-plan showing Quartz-reef at the intersection of the intrusive Greenstone and Palæozoic sediments, Gilbert River, $1\frac{1}{2}$ mile below the junction of the Robertson and Gilbert Rivers.*



A, C, D. Diorite dykes. B. Thin-bedded slates; strike E. and W., dip 75°.
E. Slate. *e.* E faulted down, apparently by intrusion of C.
F, G, H. Alternating beds of slate and sandstone.
f, g, h. Beds corresponding to F, G, H, faulted down by C and D.
I. Auriferous quartz-vein on line of fault.
J. Auriferous quartz-vein on line of contact of dyke with slate.

the Gilbert river (Fig. 14) gives a good illustration of the relation of intrusive trap-rocks to the auriferous vein-stones.

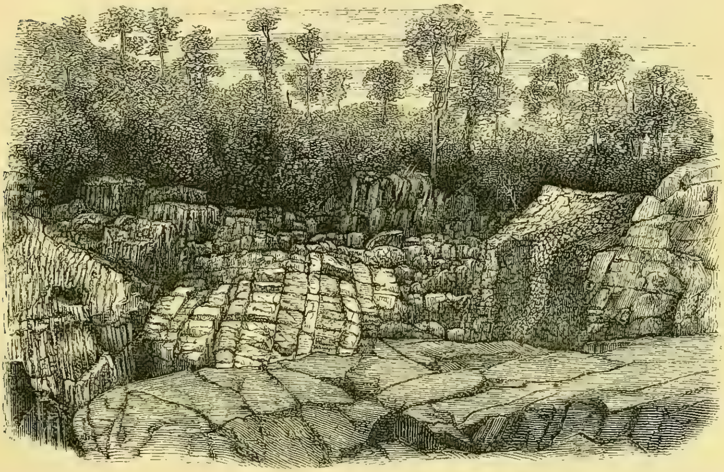
A view of the section (Fig. 15) shows also the faulting action of the intrusive rocks at this point.

In nearly all veins due to this apparent cause calc-spar and pyrites are largely represented, some of them being composed entirely of pyrites.

All vein-stones of this class are disintegrated by acid, and are rarely composed of quartz alone. The associated gold is *always* alloyed with a large percentage of silver, and assumes also much of the character of the latter metal in its native state, being filiform and dendritic. It often takes a peculiar form, combining a thread-like structure with a semicrystalline surface, which is technically known among Queensland diggers as "spider-leg" gold.

The analysis of the "spider-leg" metal, from the "Upper-Cap diggings," by Mr. Richard Smith, of the School of Mines, Jermyn Street, made with the sanction and assistance of Dr. Percy (to whom

Fig. 15.—*View showing the Intrusive Dyke of Diorite, with the Quartz-vein at the point of intersection with the Devonian Rocks, at the Junction of Gilbert and Robertson Rivers.*



I am indebted for the use of laboratory and reagents to complete the other analyses given in this paper), gave :—

Gold	89·920
Silver	9·688
Copper	0·128
Lead	0·026
Bismuth	none.
Iron	0·070
	99·832

In considering the mode in which the gold was introduced into these veins, this constant association of silver is the chief difficulty to contend with. It is evident that the solvent and precipitant must have been able to perform their functions on each simultaneously. All experiments based on the precipitation of gold alone from its solutions afford no clue to the action which has taken place in nature, where the gold, silver, and other alloyed metals are entirely homogeneous.

No case has yet been established in our museums where the gold and silver are separated in the same specimen, as is seen in specimens of native copper and silver from Lake Superior.

In several reefing-districts in Queensland, however, we have conditions that should lead to such a result by after-reduction of the silver salt.

A specimen from the "Last Chance" reef in the New-Zealand Gully, near Rockhampton, shows specks of metallic gold disseminated through a mass of chloride of silver. It has not yet been examined to see if any portion of gold may be in a form soluble in hyposulphite of soda.

From 7 tons of the vein-stuff of the "Last Chance" 240 ounces of gold were *washed*. The harder portion, which would not "puddle down" when crushed and amalgamated, yielded a bar of metal very pale in colour, and with a much higher percentage of silver than the washed-out gold from the same reef.

This was due to the abundance of "poison-stone," as the owners called the horn silver, which remained among the harder portion of the reef sent to the stampers.

Though this and other cases of a similar bearing would suggest that both gold and silver were originally in solution as chlorides (the latter by the solvent power of an alkaline chloride), yet the difficulty of precipitating the two metals together from such a solution has yet to be overcome. The more constant association of native gold with pyrites would also draw our attention in another direction.

A series of experiments now in hand may throw some light on this complicated question; and when completed they will form the material for a further communication to this Society.

Whatever may have been the solvent and precipitant of the nobler metals in the auriferous vein-stones associated with trap-intrusions, all other but hydrothermal action may safely be eliminated, the very nature of the reefs, composed as they are of alternating layers or of a promiscuous mixture of quartz, calc-spar, pyrites, &c., affording unmistakable evidence on this point. The gold also contained in the trap-dykes themselves is always accompanied by pyrites—both, in my opinion, hydrothermal products separating out during the cooling down of the trap-intrusions.

Auriferous lodes, occurring in areas where hydrothermal action has attended trap-disturbances of a special character in Queensland, are generally thin—to be estimated by inches rather than by feet; but, taken as a whole, they are far richer in gold than those enclosed by sedimentary rocks.

The yield of the principal Gympie reefs for the year 1869 was 11,996 tons of quartz for 76,870 ounces of gold, being an average of 6 ounces, 8 dwts., 4 grains per ton, the highest return of perhaps any gold-field in the world. The cost of mining such reefs, however, is much greater than where the vein-stones are better defined and of a good average thickness throughout.

The following Table, showing the thickness and yield of most of the reefs in the Rockhampton district, affords a fair representation of the character, thickness, and general conditions of the auriferous lodes found in the other mining-districts included within Palæozoic areas.

District	Name of Reef.	Thickness.	Dip.	Angle of Dip.	Country.	Yield per ton.	Pyritous or not.
District Mt. Wheeler.	Eleanor	5 ft.	E. 10° S.	45°	Serpentine.	8 dwts. to 1 oz.	Pyritous in depth.
	Hibernia	3 in. to 3 ft.	E.	50°	,,	4 dwts. to 3 oz.	Pyritous.
	Royal Alfred	6 in.	S.E.	75°	,,	4 dwts. to 3 oz.	,,
	Victoria	3 ft. to 6 ft.	E. 13° S.	35°	Talc schist.	4 dwts.	
	Gallowar	...	E.	70°	Serpentine.	2 oz.	
District Morinish.	Welcome	1 ft. to 2 ft.	E. 30° N.	30°–50°	Sandstone.	3 oz.	Copper and iron pyrites.
	Alliance	1 ft. to 4 ft.	W. 20° N.	24°	,,	18 to 25 dwts.	,, ,,
	Young Australia	4 in. to 1 ft.	W. 35° S.	30°	,,	a few dwts.	
	Nonpareil	4 in. to 1 ft.	S. 20° E.	33°	Greenstone and sandstone.	4 oz.	Pyritous.
	Pioneer	8 in. to 1 ft.	E. 20° S.	30°	Sandstone.	1½ to 3 oz.	,,
	Victoria	4 in. to 2 ft.	S. 30° E.	35°	,,	7 to 10 dwts.	
District Blackfellows.	Marie Louise	6 in. to 1 ft.	S. 40° W.	56°	Greenstone.	11 oz.	Copper and iron pyrites.
	Bull	8 in. to 5 ft.	E. 60° S.	50°	,,	1½ oz.	Pyritous.
	Blue Nose	6 in. to 8 in.	S.W.	60°–80°	Greenstone and slate.	...	,,
	Main Homeward	4 in. to 1 ft.	N.	85°	,, ,,	2 to 5 oz.	Copper and iron pyrites.
	Original Homeward	5 in. to 9 in.	S. 35° W.	25°	Greenstone.	...	,, ,,
	3rd Line Homeward-bound	6 in. to 1 ft.	S. 15° W.	50°	,,	4 oz.	,, ,,
District Crocodile Creek.	Lane's	3 in. to 7 in.	S. 10° W.	60°	,,	4 oz.	,, ,,
	Simpson's	2 in. to 5 in.	S.	85°	,,	2 to 32 oz.	,, ,,
	Cumming's	10 ft.	S. 10° W.	80°	,,	10 dwts.	,, ,,
	Hector	1½ ft. to 2 ft.	S. 25° W.	75°	,,	10 dwts.	Iron pyrites.
	Bonnie Doon	1 ft. to 2 ft.	E. 40° S.	85°	Shale.	1 to 2 oz.	Pyrites in depth.

Greenstone is here used to express that class of "trap"-rocks included in the terms "diorite" and "diabase," which are ordinarily composed of either hornblende or augite with triclinic felspar.

Where "greenstone and slate" is attached, these are "contact-reefs."

Metamorphic.

The mineral districts already opened in Queensland not situated on areas occupied by Palæozoic rocks of the Devonian epoch are:—

1. Cape River.
2. Portion of Gilbert.
3. Peak Downs.
4. Cloncurry.
5. Black Snake.
6. Kilkivan.
7. Gooroomjam.
8. Broughton.
9. Etheridge.
10. Ravenswood.

In each of these localities gold has been found in alluvial deposits, resting on rocks of a metamorphic character, derived in part from auriferous lodes, which traverse these strata. At the seven first-mentioned diggings mica and hornblende schists are the commonest forms of metamorphism developed; while at the three latter the mining-area is entirely confined to syenitic granite.

An analysis of this rock from Ravenswood gave the following results:—

Silica	60·066
Alumina	21·180
Ferrous oxide	5·533
Lime	4·833
Magnesia	2·073
Potash	2·120
Soda	2·233
Water, constitution	1·305
Water, hygroscopic	0·650
	99·993

Its contained minerals were triclinic felspar, quartz, brown mica, and a little hornblende, though some of the syenitic granites from the same locality have a much larger percentage of hornblende. This was a typical specimen of the hornblendic granites, largely developed in various localities in Queensland, which evidently have been formed by chemical and mechanical changes from stratified sedimentary rocks, as evidenced by the occasional bands of mica- and other schists observed in them at intervals.

As far as my individual observations are to be trusted, all the granites of the colony that contain hornblende in addition to mica, and the greater proportion of whose felspar is triclinic, may be classed among the metamorphic series.

The decomposition of such granites forms fair soils, yielding good grasses; and their physical aspect is that of an undulating country, with gently sloping ridges; and as a whole they are favourable to the production of other metallic minerals besides gold.

What has been asserted as to the value of certain trappean rocks in influencing the production of mineral lodes in the Devonian system, is also borne out in several of the localities enumerated above, included within metamorphic areas.

Whilst, however, the mineralizing traps of Devonian areas are generally confined to pyritous diorite or diabase, whose percentage of silica rarely exceeds one half of their total constituents, another typical intrusive rock appears to perform similar functions in the more siliceous rocks of metamorphic districts, such as those of the Cape River.

Sometimes this partakes of the character of felspar porphyry, and sometimes of a porphyrite.

It is at the intersection of these acid-felspathic dykes with the mica- and hornblende-schists, and in areas within the influence of the said intrusions, that several of the auriferous veins round Mount Remarkable, Mount Davenport, and Mount Elvan, in the Cape-River Mining-district, are found.

What the age of these metamorphic rocks relatively to the Devonian system may be is uncertain, though it is probable that they may represent the Lower Silurian series of Victoria, or the still older metamorphic system of that colony.

The richest copper lodes yet opened in Queensland, viz. "The Peak Downs" and "Mount Perry," lie within such areas. Neither of these seems to be in any way in contact with igneous dykes, but to be true lodes. The former of them had, up to the 30th June, 1870, smelted 29,168 tons of ore for a yield of 5839 tons refined copper, and had been proved, at the time of our visit at the end of that year, to extend at the 40-fathom level 1500 feet in an east and west strike, with an average width of 2 feet. The Mount Perry, lately opened, with very favourable prospects, is bounded by granite of metamorphic origin, very similar in character to that of Ravenswood.

In this last-mentioned gold-mining district nearly 200 distinct reefs are now being actively worked, the yield, from 2120 tons of the quartz first crushed from various claims, having been 5682 oz. of smelted gold, or at the rate of 2 oz. 14 dwts. per ton*.

There is no evidence of trappean action influencing the production of the veins at Ravenswood; or if there be, it is deep-seated; and there is, therefore, this practical difference to be borne in mind when considering the mode of occurrence of metallic minerals in Queensland, viz. that in the fossiliferous palæozoic equivalent of the Devonian no case has yet been observed free from trappean disturbance where paying quantities of metallic ore or metal have been found, whilst in the metamorphic areas this has not been shown to be an absolute necessity. That the stanniferous granites of the Severn river, which are now yielding such marvellous quantities of tin ore, are of metamorphic origin, seems clear from the description contained in a private letter just received by me from Mr. Aplin, lately the Government Geologist for Southern Queensland, who says:—

"The rock is a loosely aggregated, coarse-grained, highly micaceous granite, abounding in thin threads and veins of quartz. It seemed to me to be metamorphic, and was not in large bosses and broad sheets, but in numerously jointed beds.

* The total yield for 1871 from this gold-field, just received, gives 60,444 oz of gold.

"The tin crystals are principally associated with the quartz in the most highly micaceous portions."

And, speaking of the alluvial drifts from these stanniferous granites, he adds:—

"*Their richness and continuousness is extraordinary, and, I should think, quite unparalleled in any other country.*"

In the metamorphic system, indeed, is the most varied development of metallic ores in Queensland; in it also the greatest number of "true lodes" have been found; and this fact affords the best reason for the supposition that the comparatively unexplored districts at the heads of the Mitchell and in the McKinlay ranges, where large tracts of metamorphic rocks are known to exist, will yet add very much to the mineral exports of Queensland when thoroughly prospected. From the exploring expedition about to start into the former of these districts great results may be expected.

Granitic.

Outcrops of granite extend along the eastern coast of Queensland from Cape York nearly up to Broadsound, and inland as far as the heads of streams running direct from the inner coast range to the sea.

Isolated patches of the same character of rock are found at intervals from the seaboard back to the coast range, going south from Broadsand.

Very little rock of this character is met with west and south of the dividing range which separates rivers flowing to the eastern and northern coast and those trending south to the Murray or Coopers' Creek.

In their lithological character, the granites of Queensland vary very much in their crystalline texture and arrangement of minerals in the same rock-masses, passing from true granites into porphyry and quartz-porphyry; but the monoclinic felspar is *always* in excess of the triclinic.

With the exception of molybden-glance, found in the porphyry near Townsville, no metallic ores are associated with the granites proper.

Trappean.

In a previous portion of this paper much stress has been laid on the value of certain intrusive Trap-rocks as specially influencing the production of auriferous veinstones in Queensland; and it is now proposed to investigate this subject somewhat more in detail.

The petrology of these may be divided into four type classes:—

1. *Pyritous* porphyrites and porphyries.
2. *Pyritous* diorites and diabases.
3. *Chrome-iron* serpentines.
4. *Pyritous* felsites.

Group 1.

The analysis of a characteristic specimen of a porphyrite of Group 1 (Pl. XI. fig. 2) gave the following results:—

Silica	61·433
Alumina	20·293
Ferric oxide	1·220
Ferrous oxide	3·260
Lime	3·233
Magnesia	1·566
Potash	1·686
Soda	6·173
Water, constitution	0·725
Water, hygroscopic	0·300
Specific gravity 2·712.	99·889

Mr. Allport's description of this, from a microscopic examination, was :—"That it was an altered porphyrite, with pseudomorphs after felspar, in a granular felsitic base, and contained minute grains of magnetite, and also a little chlorite." The specimen analyzed did not contain pyrites, but was slightly tinged with carbonate of copper in the mass, a portion not so stained being selected for the determination of the ingredients.

Rocks of this type, associated with auriferous veins, are developed in the Black Snake "reefing districts," on the flanks of the Berserker Range (Pl. XI. fig. 3), in New-Zealand Gully, and in other mining-areas near Rockhampton, also within the auriferous radius around Mount Wyatt.

Group 2.

Pyritous Diorite and Diabase.

In the chapter on the Palæozoic rocks, correlated with the Devonian of Europe, the analysis of a type specimen of the Gympie crystalline Diorite is given. That of a diabase tufa, containing organic remains, which forms an interstratified portion of the Devonian series, the one probably representing the core, the other the ejecta, of a Devonian volcano is also given.

As this group, however, is widely distributed along the eastern portions of Queensland, and seems so important an indicator of auriferous wealth, the analysis of another specimen (Pl. X. fig. 3) taken from near the junction of Granite and Twenty-mile Creek, in the Gilbert district, is here given.

Ultimate Analysis.

Silica	47·465
Alumina	19·485
Ferric oxide	1·570
Ferrous oxide	11·735
Lime	7·400
Magnesia	5·670
Sulphur	0·335
Potash	0·280
Soda	2·725
Carbonic acid	1·461
Water, constitution	1·150
Water, hygroscopic	0·350
	99·626

Of this Mr. Allport says:—

"It contains a fibrous green mineral, which appears to be hornblende, partially altered; the felspar is very opaque and indistinct in form.

"The base contains much chlorite and a few blebs of quartz, together with a little epidote.

"The rock is highly altered; and if the green fibrous mineral should turn out to be uralite, it might then be called a diabase."

All the rocks of this group, indeed, are much altered, generally in the direction of serpentine; their specific gravity varies from 2·700 to 3·100, according to the proportion of pyrites, hornblende, or chlorite entering into their composition. The general facies corresponds with that of the intrusive dykes of the Wood's Point District, in Victoria, where similar geological conditions produce similar mineral results.

Group 3.

Chrome-iron Serpentines.

The serpentines containing chromic iron, rarely pyrites, are in my opinion simply altered forms of Group 2.

In the Gladstone, Cawarral, and Kilkivan districts, there is constant evidence of this; and in the first-mentioned district it is especially marked.

Group 4.

Pyritous Felsite.

This group is very sparingly represented in Queensland, the most noticeable instance being that of Mount Wheeler, the analysis of which by the late Professor Thompson, of the University of Sydney, is as follows:—

Mount Wheeler "Felsite."

Undecomposed by HCl	96·75
Decomposed ,, ...	3·25

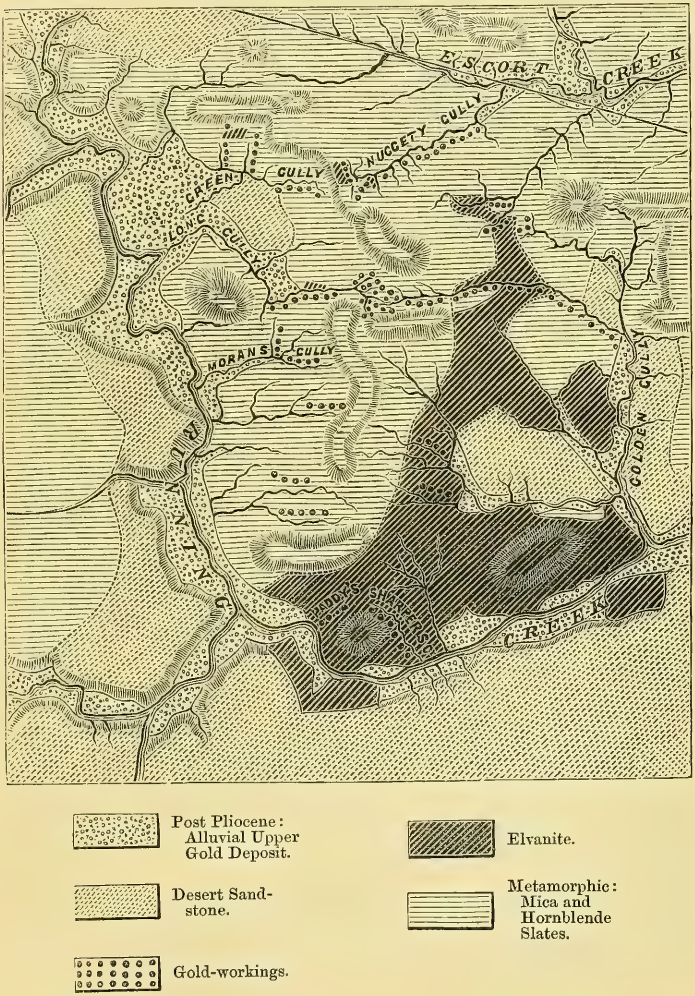
Undecomposed.		Decomposed.	
Silica............	76·28	Silica	36·54
Alumina	12·64	Alumina	23·97
Ferric oxide	0·92	Ferric oxide	11·59
Ferrous oxide	0·85	Ferrous oxide	none.
Lime............	0·33	Lime	1·57
Magnesia	trace	Magnesia	trace.
Potash	3·30	Potash	1·14
Soda	4·59	Soda..............	2·00
Water	0·16	Water	19·98
	99·07		96·79

Specific gravity 2·564.

This rock rises abruptly to an elevation of 800 feet, through serpentine, gabbro, and diallage rock. It is very close-grained and compact. From a microscopic examination, Mr. Allport gave the following description:—

"This is a felsite or trachyte, and consists of a fine, granular

Fig. 16.—*Plan of a portion of the Cape Mining-district, showing a dyke of Felsite traversing Metamorphic Schists.*



felspathic base, in which there are scattered groups of minute green grains and crystals of hornblende."

Professor Thompson's analysis would agree well with the former portion of the microscopic determination; but the soluble portion is rather difficult to understand, there being no appearance of a highly hydrated silicate in the rock.

Be this as it may, around Mount Wheeler, within a radius of a mile the serpentine is traversed by auriferous reefs, whilst the extension of the same band of serpentine over a large area beyond this contains no parallel to the auriferous area round the above-mentioned hill.

Some 30 yards from the bluff face of the Mount, the serpentine was found to contain gold sufficient in quantity to pay for mining to a depth of 20 feet below the surface; gold was also found even to a depth of 80 feet, but not in remunerative quantities. This was known as "Block's Claim;" and it affords additional ground for believing that the intrusion of Mount Wheeler was an active cause in the mineralization of the country around it.

In the Cape-River district, the influence of this class of felsite dykes is particularly marked; and it was whilst in the preparation of a detailed map of this gold-field that the practical value of these conditions was first realized by myself.

A plan of one of these dykes, which occupy the whole of Paddy's and Sharper's Gully, and cross Golden and Nuggety Gullies at their richest points, is here reproduced (Fig. 16) from the published map of the Cape Gold-field, in order to afford a crucial example of this mode of gold production.

At the intersection of this dyke with the quartzites and mica-slates of the metamorphic series, a fine example of a friction-breccia is seen on a steep hill-slope about one third of a mile from the junction of Paddy's Gully with the Running Creek, up to its junction with Golden Gully.

The gold found in Paddy and Sharper's Gullies was either in the form of losely aggregated fine gold, forming spongy nuggets, or very fine dust, the material adhering to which was a more or less decomposed form of the felsite.

The detritus of this formed the "wash-dirt," and the rock itself the "bottom," or "bed rock," of those miners who were fortunate enough to obtain claims in either of these rich gullies.

Large patches of soil on the slopes leading to these watercourses, and on the watershed between Golden and Nuggety Gullies, were leased for "surfacing," the character of the gold and rock being the same in all these cases.*

* The analysis of Paddy's-Gully gold, by Mr. R. Smith, gave:—

Gold	92·800
Silver	6·774
Copper	0·048
Lead	0·048
Bismuth	traces
Iron	0·014
	99·684

An analysis of this Paddy's-Gully felsite afforded me:—

Silica	70·800
Alumina	19·186
Ferric oxide	1·164
Magnesia	0·827
Potash	1·826
Soda	1·208
Water, constitution	3·250
Water, hygroscopic	1·425
	99·686

The appearance of the rock is that of a partially decomposed felsite or trachyte, in which a portion of the alkali of the felspar has been replaced by water, and kaolin formed, as has no doubt been the case.

The peroxide of iron is evidently the representative of pyrites, as it partially fills cubical cavities in the decomposed rock, and forms no portion of a silicate.

Though the probabilities all tend to the assumption that this felsite was the absolute matrix of the gold found in the ravines which intersect it, still we are not able to make the definite assertion, not possessing sufficient material to concentrate the heavier particles by crushing, washing, and determining the presence of gold by assay. In rock of the same character, however, in another portion of the same gold-field, this fact is beyond a doubt.

At the Upper Cape diggings are two so-called reefs, viz. "Green's" and "The Tunnel," which are of the same material, and of which many tons were crushed, with a yield of from 6 to 8 dwts. of gold per ton, and an unlimited supply of material.

The analysis of this stone afforded me:—

Silica	74·000
Alumina	16·137
Ferric oxide	0·963
Magnesia	0·627
Potash	3·791
Soda	0·987
Water, constitution	0·750
Water, hygroscopic	2·650
	99·905

Specific gravity 2·451.

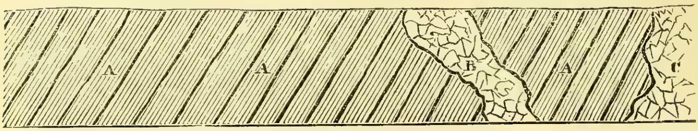
This was really a dyke of felsite, differing, as will be seen, very little in composition from that of Paddy's Gully; but the decomposition of the felspar had not proceded so far into the kaolin element.

The section in the tunnel by which the "Tunnel reef" was worked, is here sketched (Fig. 17).

As neither of these paid the working-expenses, they were abandoned, and now remain unworked.

In the neighbourhood of Rockhampton, at the so-called "Cumming's reef," however, parallel conditions occur, and several hundred tons of rock were crushed with remunerative results, until the

Fig. 17.—*Section in Tunnel Claim, "Upper Cape Diggings."*



A. Mica and hornblende schists.
B. Dyke of felspar porphyry cutting the schists nearly at right angles to their dip.
C. Dyke of felsite mined for gold.

water-level was reached, when the necessity for a supply of expensive pumping machinery checked the enterprise for a time.

The analysis of the auriferous matrix of Cumming's Reef afforded me:—

Silica	69·900
Alumina	12·737
Ferric oxide	4·413
Oxide of copper	1·875
Magnesia	0·130
Potash	0·600
Soda	6·539
Loss at red heat	3·500
	99·694

The analysis agrees with the examination under the microscope, which indicates its approximate composition to be:—

	Per cent.
Quartz	10·000
Triclinic felspar	80·000
Decomposed pyritous element	10·000

The iron and copper are produced by the decomposition of pyrites, the iron being chiefly in the form of brown iron-ore, and the copper occurring as silicate. A little titanic acid and manganese were found, but not quantitatively ascertained, the object of the examination being to determine the alkalies, and so approximately the felspar element.

This so-called "reef" is 10 feet wide where worked; and the walls are composed of micaceous diorite. A nearly parallel case is mentioned by the geologist of Southern Queensland as occurring at Ban Ban, in the Gayndah district. He says, "There is no appearance of a mineral lode or vein of any kind on the spot. The material, of which three tons were sent to the Sydney Mint for assay, which resulted in a return of one ounce six dwts. of gold per ton, was taken from a mass of partially decomposed felspar porphyry, probably a dyke, but exhibiting no traceable outcrop. It is in a loose rubbly condition, and is exposed in a somewhat abrupt face on one side of a broad gully running into Sandy Creek, a tributary of Barambah Creek. Infiltrations of green and blue carbonate of copper form thin films and coatings on the numerous surfaces produced by disintegration of the rock; and oxide of iron now fills the cavities once occupied by crystals of pyrites. Both the copper and the gold have doubtless been derived from the decomposition of auriferous pyrites, which appear to have been developed sporadically through the mass, and not collected into veins."

Taking, then, the case of "Green's reef" and the "Tunnel claim" to prove the occurrence of gold *per se* in group 4, the Ban Ban and Cumming's so-called "reef" would be parallel cases for group 1.

The Canoona Diggings would seem to afford the best evidence of gold occurring *in situ* in serpentine. Here a gully has been worked from its head for three quarters of a mile down its course, the bed-rock being serpentine only, the wash-dirt a brown serpentine clay. When the gold was found with the matrix attached, that matrix was serpentine. The "puddlers" in this gully have been continuing their operations for years. After washing and rewashing the clay detritus, they now take a little more of the decomposed undrifted serpentine, and from this source still obtain a bare subsistence, with sometimes, as they say, a "little find."

The case of "Block's claim," under Mount Wheeler, may be due to hydrothermal action attending the intrusion of the felsite of the Mount; and the gold cannot, therefore, be assumed as originally present in the serpentine.

Of No. 2 (the diabase and diorite group), from individual experience we can make no assertion as to the presence of gold through the mass of the rock, since a large collection of pyrites obtained from various auriferous districts in Queensland, which were intended for assay, was found to be distributed throughout the case containing them, when this case was fished up from the wreck of the 'Queen of the Thames;' the specimens were therefore useless for the purposes for which they were collected.

The evidence of Mr. Aplin, the late Government Geologist for Southern Queensland, as bearing on this point, may, however, be adduced. Speaking of the Gooroomjam diggings, he says:—

"Gooroomjam is situated on that portion of the Bunya range which divides the sources of the Brisbane river from those of the Burnett.

"The diggings are confined to two gullies that descend from either side of the range.

"The one is worked for about a mile and a half in length; the latter for even a less distance than this. Both are nearly worked out; and there is little probability of a further extension of either.

"The area mined on consists entirely of greenstone, with the exception of the lower portion of the workings on Monarumbi Creek, a mile or so below the lower township, where massive hornblendic schists crop out at the foot of the range on the north side of the creek, and granite on the point of the spur constituting the south bank.

"But I believe that the little quantity of gold found here has travelled down the creek from the tract of greenstone above, and that the whole of the gold has been derived from the latter rock. No quartz fragments are to be seen on the surface, and scarcely any are ever found in the drift constituting the wash-dirt."

In the Jermyn-Street Museum a fine example of gold in diorite, from the Woods Point District in Victoria, where similar conditions obtain, is open for inspection.

Although these instances have been pointed out to show the absolute presence of gold throughout the mass of certain eruptive trap-dykes, it is by no means our intention to assert that the noble metal will be often found in sufficient concentration in this form to become a source of supply in any material degree.

In my opinion, however, these four groups of trappean rocks are very important as indicative of the period at which the gold was deposited in the veins of quartz, calc-spar, pyrites &c. which are found at and near their intersection with Palæozoic and Metamorphic strata, as well as in the trap-rocks themselves.

The study of these peculiar vein-stones has led me to the conclusion that the fractures which they occupy were due partly to the bursting power of the elastic vapours preceding the welling up of the viscid trap into a portion of these rents, and partly to the contraction in cooling and crystallization of the intruded mass itself.

The vein-stones themselves are probably deposits of mineral matter from the hydrothermal action *which preceded, was contemporaneous with, and continued long after the trap itself had cooled down.*

This action was similar to that of the Steamboat Springs in America, cited by Blake and John Arthur Phillips.

This may have been, and doutbless was, supplemented by infiltration from the trap-rocks themselves, the calc-spar element, so characteristic of this class of lode, being probably supplied from this source; for, *as a rule,* the sparry portion of the ore is poorest in gold.

An exception to this rule is exemplified in a specimen previously alluded to from the Caledonian Reef, Gympie, where the gold is seen traversing calc-spar and quartz indifferently, the quartz crystals being quite isolated in a menstruum of the spar. Again, in another specimen it will be seen that in a breccia-lode where angular fragments of quartz are cemented by carbonate of lime and brown oxide of iron, the gold affects quartz, lime, and iron without respect to affinities. Another shows a nugget of gold and carbonate of bismuth, a portion of which, treated with hydrochloric acid, proved that much of the gold was isolated from the larger portion, as if the bismuth and gold had been originally precipitated together.

The very nature of the veins shows that they never can have been subjected to any heat sufficient to cause fusion, but are due entirely to aqueous action.

With regard to the age of these dykes much has yet to be learned. From all the evidence collected I should be inclined to place their succession in time as follows:—

1st. The porphyrites and porphyries range from the Metamorphic to the Devonian.

2nd and 3rd. The diorites, diabases, and serpentines range through all the Devonian period, the action being most intense in the lower portion of the series; and the interstratified diabase ashes and tufas at Gympie favour this idea.

4th. The trachytes and felsites are of uncertain date, but are certainly younger than Group 2.

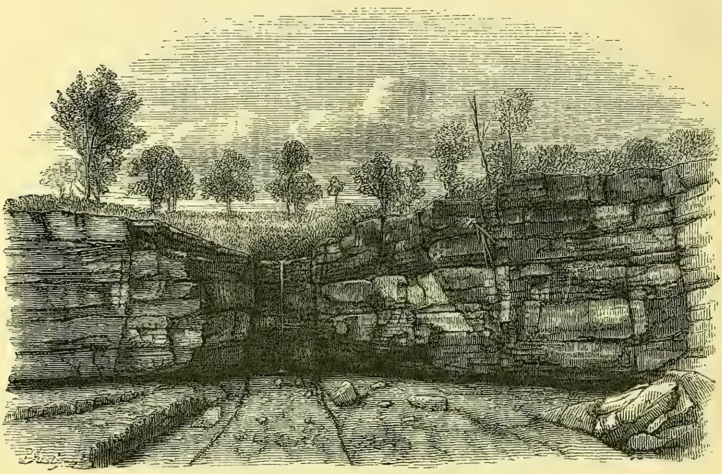
The true Carboniferous and Mesozoic Carbonaceous of Eastern Queensland are constantly penetrated by trap-dykes; but, *with one exception*, these are dolerites, differing in no respect from the older and newer Tertiary volcanic series of the colony, *and no vein-stones*

Fig. 18.—"*Dolerite" Dyke traversing "Desert Sandstone," Granite Creek, Gilbert District, Northern Queensland.*

of any kind are found in the bounding strata, neither is alteration observed at the point of contact (see Figs. 18 & 19).

The exception occurs at Brisbane, where a dyke of quartz porphyrite cuts through, and is interstratified with, the Mesozoic strata

Fig. 19.—*Horizontal Coal-Measures cut by Trap-dykes, Pelican Creek.*



there developed; but its character is quite different from those of Group 1.

At Gladstone a dyke of the only true trachyte yet met with in the colony is quarried for building-stone (Pl. XI. fig. 1). Its analysis afforded me

Silica	67·800
Alumina	14·666
Ferric oxide	5·350
Potash	5·653
Soda	4·600
Water, constitution	0·700
Water, hygroscopic	0·600
Specific gravity 2·320.	99·369

This rock resembles the trachyte of the Puy-de-Dome. Crystals of sanidin felspar occur in a crystalline felspathic base, the iron being in finely disseminated scales of iron-glance throughout the mass. No mineral veins occur in or near it. It traverses the Devonian series of the district; and although there is no proof of its relative age, it has the appearance of a modern rock.

The active influence of these trap disturbances of various periods seems in Queensland to have been confined to the strip of country lying about 200 miles back from, and parallel to, the eastern coast, and along the Carpentaria watershed. The vast Cretaceous and Oolitic tracts lying to the westward of this line would seem to be entirely beyond their limit of action.

Volcanic.

Whilst the older *Trappean rocks* have apparently had so much influence on the disturbance and fracture of the sedimentary strata older than the Carboniferous, and by a secondary process have evidently been centres of mineralizing action, the *volcanic* seem to have played the most important part in determining the elevation and present physical outline of North-eastern Queensland.

As will be seen by reference to the Map (Pl. IX.), the main outbursts of lava have taken place along the dividing range which separates the eastern and western waters, and therefore on the line of the highest elevation of the country.

The more northern volcanic areas, those shown on the Map north of latitude 21°, are probably contemporaneous with the "upper volcanic" series of Victorian geologists, so extensively developed in the western districts of that colony. These have issued from well-defined craters still in existence, and are probably of Pliocene Tertiary age.

The *southern* areas, viz. Peak and Darling Downs &c., are older, agreeing with the "lower volcanic" of Victoria, which have been ejected through fissures, and have in no case a very extensive flow, beyond the lines of fracture through which they issued. These may be referred to the Miocene Tertiary epoch (Pl. XII. figs. 1 & 2).

The rock-masses forming both the "upper" and "lower" volcanic are basic in character, and may, with rare exceptions, be all grouped under the general term "dolerites."

Mr. Allport's description of a typical specimen from the Clarke river, with minor modifications, will hold good for most of the volcanic rocks of Northern Queensland (Pl. XII. fig. 3).

He says:—"This dolerite contains a triclinic felspar, augite, magnetite, pseudomorphs after olivine. The felspar prisms are clear and transparent, and exhibit well the striæ and bands of colour when examined in polarized light. The augite occurs in small brown crystals and grains; it frequently contains black magnetite, and is sometimes slightly altered. The olivine has been completely altered to iron oxide, and appears in the sections as bright red grains and crystals. Pseudomorphs of quite similar character occur in the dolerites and basalts of the coast of Antrim."

After the examination of several specimens from various localities, he adds:—"These are characteristic felspathic dolerites, and contain neither nepheline nor leucite."

The single exception that came under my observation in the upper volcanic was that of an interstratified bed of a highly siliceous rock, in which nearly one half the mass was composed of quartz crystals arranged in a quartzose matrix.

The "lower volcanic" are, as a rule, far more altered and decomposed than the upper, and assume more the amygdaloidal character, the usual occupants of the cavities being zeolites or calc-spar.

The most prominent cases in which ores of metallic mineral occur in either of these volcanic series are in the Collaroy Ranges, near the Collaroy Station, and on the Bowen river, near M'Dougal's Station, where, in two special bands of the older volcanic, an epidote rock contains spangles and small nodules of metallic copper, and a prehnite amygdaloid is sparingly permeated by sulphide and carbonate of copper.

The analysis of the epidote rock gave me:—

Silica	42·380
Alumina	24·905
Ferric oxide	7·785
Ferrous oxide	0·210
Lime	19·565
Magnesia	2·145
Soda	0·590
Potash	0·185
Copper	0·400
Water, constitution	0·975
Water, hygroscopic	0·825
	99·965

The amount soluble in hydrochloric acid was 66·275 per cent.

The soluble portion was composed of:—

Silica	37·043
Alumina	26·873
Ferric oxide	8·698
Ferrous oxide	0·316
Lime	21·193
Magnesia	2·346
Copper	0·635
Water, constitution	1·471
Water, hygroscopic	1·244
	99·819

The insoluble portion was composed of:—

Silica	52·112
Alumina	20·947
Ferric oxide	5·960
Lime	16·382
Magnesia	2·208
Soda	1·749
Potash	0·549
Specific gravity, 3·172.	99·907

This rock is probably made up of two varieties of epidote, one yielding more readily than the other to hydrochloric acid. The alkalies present doubtless represent a proportionate percentage of felspar, though a section for the microscope has not been prepared sufficiently thin to obtain information on the latter point.

The analysis of the prehnite rock afforded me :—

Silica	42·033
Alumina	21·606
Ferric oxide	8·829
Lime	23·633
Water, constitution / Water, hygroscopic	2·900
Copper carbonate	0·825
Specific gravity 2·844.	99·826

After examination under the microscope, Mr. Allport says of this rock :—

"It must have been originally as scoriaceous as any recent lavas, but now forms a hard solid mass of zeolitic mineral matter.

"All the cavities are filled with prehnite, in radiating groups of crystals, which exhibit a magnificent display of colours when examined in polarized light.

"One cavity is lined with the radiating prehnite, and the central portion filled partly with calcite, and partly with green carbonate of copper.

"Of the original constituents nothing is left except the magnetite. The forms of felspar crystals are sharp and distinct; but the original substance has been removed, and replaced by prehnite, differing in no respect from that filling the cavities.

"The reddish-brown grains and patches scattered through the base probably represent the augite."

It is interesting to observe how nearly these cupriferous altered dolerites resemble in composition the interstratified cupriferous traps of the Potsdam-sandstone series in the Lake-Superior district in America.

Near the Dotswood Station, on a tributary of the Burdekin river, metallic copper, imbedded in a quartz matrix, has been observed in thin irregular patches.

The rock enclosing this is amygdaloidal dolerite, itself containing a little copper and copper-ore, but only near the patches of quartz.

Near the Mount Coora almost the same conditions of cupriferous impregnation of decomposed dolerites obtain; but in these cases the ores seem to be the result of the decomposition of pyritous bands in the rock, rather than a repetition of the conditions observed on the Bowen river and near the Calliope Station.

On Agate Creek, a tributary of the Gilbert river, a local volcanic outburst of no great extent is met with, the cavities in a thick band of melaphyre, which forms a portion of this flow, being filled with agate and carnelian. This resembles in general character the agate melaphyres of the Vaal river in South Africa, the diamond-producing district.

On the Burnet river, in Southern Queensland, melaphyres of the same character are met with.

The Desert Sandstone is seen resting on the Agate-Creek melaphyres, and also on the "older volcanic" dolerites near Morinish, in fine sections; and, where available, this would afford the best guide for the separation of the two great Tertiary volcanic periods of Queensland. It also gives a good relative horizon to that great unfossiliferous sandstone formation which, as previously mentioned, seems to have extended during the Cainozoic period over the greater portion of Australia.

The volcanic soils of Queensland are those best adapted for the grazier and agriculturist.

To epitomize:—

It may be stated that, with the exception of the McKinlay ranges, a line drawn parallel to the eastern coast, at a distance of 250 miles, would include all the palæozoic, metamorphic, granitic, trappean, and volcanic rocks represented in the colony, both coal-groups lying within the same area.

The Mesozoic and Cainozoic systems occupy the surface area to the westward.

The volcanic rocks follow the line of greatest elevation on the main watershed, at altitudes from 1500 to 2000 feet above the sea-level.

The descent, going eastward, is first, locally, a thin capping of Desert Sandstone, next Carboniferous, then Devonian (and possibly Silurian), with patches of metamorphic and granitic rocks interspersed.

The chief granitic mass extends from Broad Sound to Cape York*, with an occasional capping of Desert Sandstone.

Westward from the dividing range, Desert Sandstone and the Cretaceous and Oolitic groups alternate one with the other to the extreme limit of the colony.

Areas of Formations.

Estimating the entire extent of the colony at 600,000 square miles, a rough approximation to the areas occupied by the different geological formations is as follows:—

		Square miles.
Alluvial		20,000
Desert Sandstone	Cainozoic	150,000
Cretaceous, Oolitic	Mesozoic	200,000
Carbonaceous	Mesozoic	10,000
Carboniferous	Palæozoic	14,000
Devonian and Upper Silurian	Palæozoic	40,000
Metamorphic		20,000
Granitic (including Cape-York peninsula)		114,000
Trappean		12,000
Volcanic		20,000
		600,000

* See also Quart. Journ. Geol. Soc. vol. xxv. p. 297 *et seq.*, for an account of the granite and other rocks of the Cape-York peninsula.

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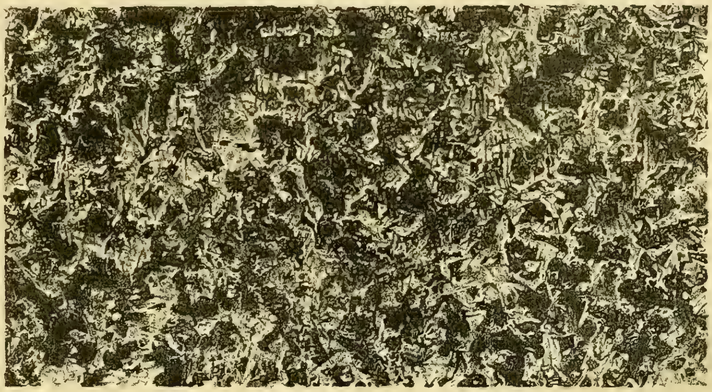

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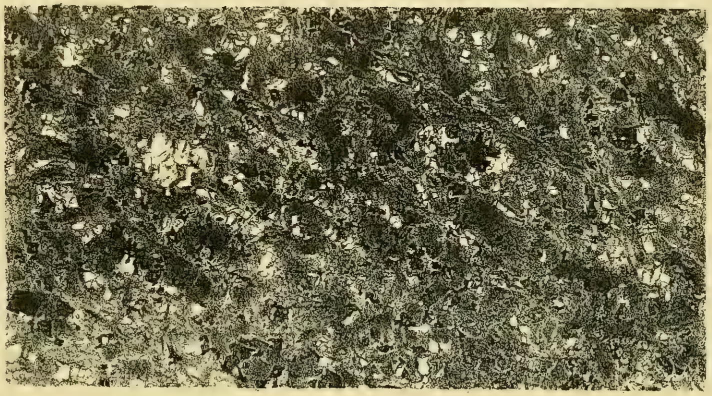

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DIORITES FROM QUEENSLAND.

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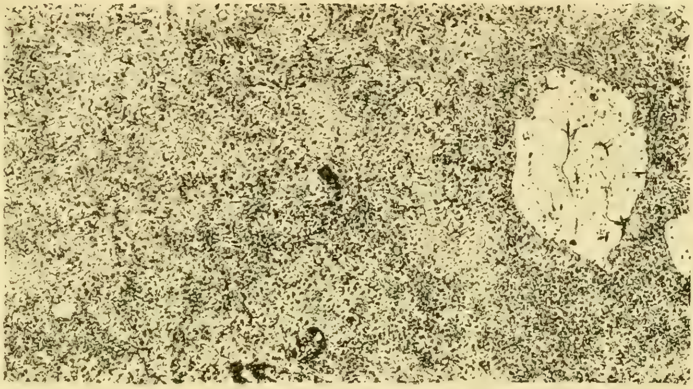

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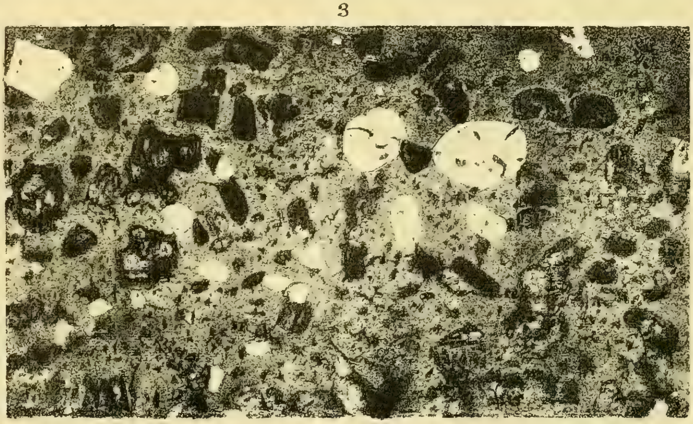

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TRACHYTE AND PORPHYRITES
FROM QUEENSLAND

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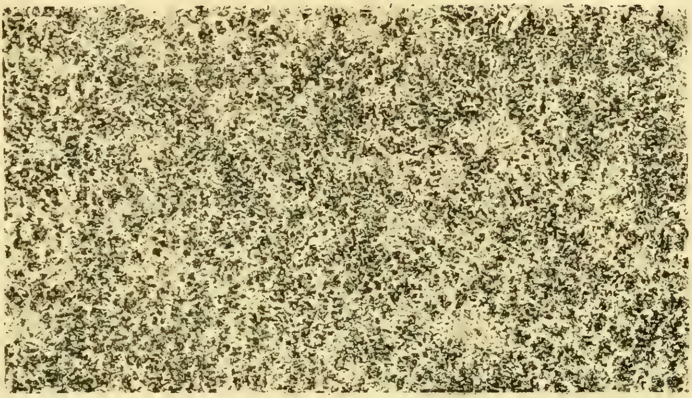

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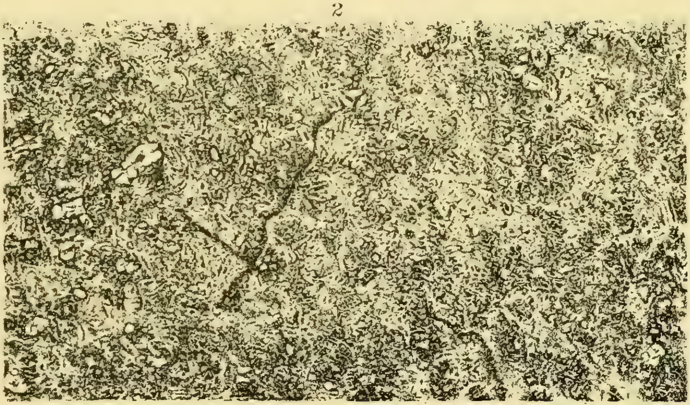

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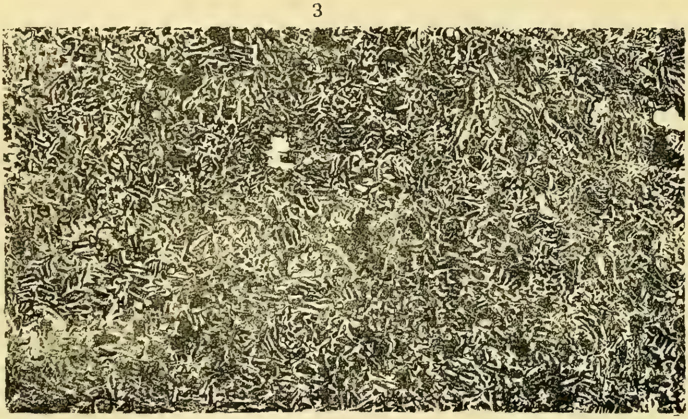

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DOLERITES FROM QUEENSLAND

Or

Valueless land, "Desert Sandstone."		150,000
Scrubby and thickly timbered, inferior pastoral, but valuable as containing coal, iron-ore, &c.	Carbonaceous &c. Mesozoic and Palæozoic	24,000
Fair pastoral, and valuable for its associated minerals and metals	Devonian, Silurian, Metamorphic	60,000
Fair pastoral	Granitic	114,000
Good pastoral	Cretaceous and Oolitic	200,000
First-class pastoral and agricultural	Alluvial, Volcanic, Trappean	52,000
		600,000

Looking at the matter from an economical point of view, we find that one fourth of the colony of Queensland is valueless, whereas three fourths furnish good pastoral land.

Of this latter, 60,000 square miles contain extensive and very valuable mines of gold, with numerous outcrops of copper- and lead-ores, to which may now be added rich deposits of tin-ore; 24,000 square miles are capable of producing illimitable supplies of coal and iron; 52,000 square miles are, as far as soil is concerned, best adapted for the agriculturist and squatter.

In conclusion, it may be asserted that there is here a wealth of material resource which compares favourably with that of any other Australian colony.

Appendix I.

Description *of the* Palæozoic *and* Mesozoic Fossils *of* Queensland. By Robert Etheridge, Esq., F.R.S., &c., Palæontologist to Her Majesty's Geological Survey of Great Britain.

Introduction.

Mr. Daintree's late explorations in Queensland have added much to our knowledge of the distribution of extinct life over that extensive colony. A slight history or *résumé* of the progress of geological and palæontological discovery in Australia may not be out of place, and will show the difficulties attending research in a country almost untrodden and only, of necessity, very partially examined. It is hoped that the local societies may be induced to work up the varied and rich fossil fauna surrounding those cities now so extensively peopled in New South Wales, Queensland, and South Australia; and it is partly with this view that we are induced to figure the species found fossil in Queensland, many of which are new, and a few common to Asia and Europe. A knowledge of the wide distribution of identical forms and extension of old seas, under different conditions, can only be established by the united labours of many in the same field of investigation. India is now being well explored, America equally so. Southern Africa is being gradually examined; and much of Victoria has been carefully surveyed; yet we know little of the real palæontology of Australia, owing to the few published *detailed* descriptions and figures of the fossil fauna of the stratified rocks of the country. The labours, however, of the Rev. W. B. Clarke upon the spot, and of Professor Owen and Mr. Moore England, have thrown some light upon the distribution of extinct life in those rocks.

At the request of Mr. Daintree, I have examined the series of fossils brought home by him, and have selected those species capable of description. I have described thirty-eight new forms, and recognize ten others that are common to England and the colony; it is almost entirely amongst the Palæozoic remains that this agreement is found, and through the Cœlenterata (or Actinozoa) and Brachiopoda (which, perhaps, we should expect) rather than through the higher groups. Amongst the Lamellibranchiata it can scarcely be said that we possess any shell common to the two areas; but a variety of *Panopæa* (*Mya*) *plicata*, Sow., occurs; and this with us is a Lower and Upper Greensand and Gault species. One Ammonite, *A. Beudanti*, D'Orb. (or a closely allied form), seems rather abundant in the "Hughenden" Cretaceous beds; this variety I have named *A. Mitchelli*. The group Ligati is represented by one species from the Mackinlay range; it differs little from the French and English Upper Greensand and Chalk forms. This, the *A. Sutherlandi*, mihi, is the only species of the group at present recorded or known to occur in Australia. We have also a doubtful *Crioceras* of considerable size, but scarcely well enough preserved for description. No secondary or Mesozoic Brachiopoda occur in Mr. Daintree's series, although Mr. Moore described seven species from the Wollumbilla collection *. Systematic search *in situ* over the area in rocks of deeper-sea accumulation may bring to light species of this widely spread group of Mollusca.

Only two Devonian, two Carboniferous, and one Cretaceous species of Gasteropoda occur, or five in all.

The Devonian and Carboniferous faunas number twenty-seven species, nine being common to England and Queensland. The Cretaceous twenty-five, two of which are British. Eight other forms occur, which I believe are of Oolitic age; but their condition is such that no true description can be given of them; they are, however, figured on Plate XXV. From the Hughenden Cretaceous beds we have the caudal portion and scales of a large species of *Aspidorhynchus*, a genus which, so far as we know, occurs in England in the Lias, Oxford Clay, and Purbeck beds. Associated with these fish-remains there is, apparently, the bone of an *Ichthyosaurus*.

* Quart. Journ. Geol. Soc. vol. xxvi.

History.

So early as 1831-2*, Major T. L. Mitchell, Surveyor-General of Australia, brought Palæozoic fossils from the basin of the Hunter river, and submitted them to Mr. J. D. Sowerby for identification. These appear to have been Carboniferous ; for *Atrypa glabra* and *Spirifera* are mentioned amongst the few forms occurring.

Shells resembling *Astarte* and *Hippopodium* are also mentioned, of which latter there were four species named by Mr. Sowerby; *Megadesmus*, an Isocardiiform shell, and *Trochus* (*T. oculus*) complete the list. No conclusions as to age or stratigraphical position were attempted, either by the explorer or Sowerby, it being evident that they had not materials enough upon which to base reliable conclusions.

A. R. C. Selwyn, Esq., in 1858†, mentioned in a letter to Prof. Ramsay, having in his possession many known and new forms of Silurian fossils, and that Prof. M'Coy was about to examine, describe, and figure the new species; this, however, does not appear to have been done.

Mr. Selwyn distinctly describes the occurrence, near Melbourne, of the equivalents of the May-Hill Sandstone of England, and, to to the eastward, of a gradually ascending series, including Wenlock, Ludlow, Devonian, and true Carboniferous rocks, with Oolitic coal-bearing beds, resting unconformably upon the Palæozoic strata. Selwyn also recognized to the westward, towards Ballarat, a descending series, believing them to be Cambrian; he also mentions that about sixty Silurian genera occur in that area, and many new species; these are all enumerated in Mr. Selwyn's paper (*loc. cit.*); but owing to genera *only* being mentioned, and the chief occurring in the older Palæozoic rocks, they are of little value for a general table of distribution.

In 1860 the Rev. W. B. Clarke, M.A., published‡ a valuable contribution to the history of Australia. In the appendix, p. 282 (H), "*Fossils of the Southern Districts,*" Mr. Clarke refers to the assistance received by him from Mr. Lonsdale and Mr. J. W. Salter in determining the Silurian, Devonian, and Carboniferous species ; and a copious horizon-table is given at pp. 285 and 288. No less than 269 fossils are enumerated, but only 124 species determined; the genera therefore have little value. At p. 284 Mr. Clarke refers to the resemblance, if not identity of the Carboniferous species of Australia with those of Ireland, as determined by Prof. M'Coy (Ann. Mag. Nat. Hist. vol. xx.). "We find," says M'Coy, "so extraordinary and unexpected an amount of agreement between those beds and the similar Shales, Sandstones, and Inferior Limestones forming the base of the Carboniferous system in Ireland, that it is impossible not to believe them on the same parallel, and there is equal

* Three Expeditions into the interior of Eastern Australia, Australia Felix, and New South Wales. By Major T. L. Mitchell, F.G.S., 1838 (now Lieut.-Colonel Sir T. L. Mitchell, C.B.).

† Quart. Journ. Geol. Soc. xiv. p. 533, 1858.

‡ 'Researches in the Southern Gold Fields of New South Wales,' Sydney: 1860.

difficulty in imagining them to be either younger or older than those deposits." MM. de Verneuil and Barrande also especially notice the agreement of certain forms with those of Australia.

F. T. Gregory, Esq., in 1861*, gave to the Society a geological sketch of a part of Australia, the result of nearly thirty years' residence in Western Australia.

The area geologically explored was the Darling range and the country to the eastward. Mr. Gregory states that he had been unable to procure any positive proof of the existence of rocks of Silurian age—though, judging by analogy, there is reason to suppose they might occur; he states that the rocks comprising "Mount Barren Ranges" are the only ones bearing any Silurian character or holding that relative position with regard to other formations. He next assumed that the Devonian series occurred in the form of compact felspathic clays, sandstones, and ferruginous conglomerates, capping the tableland of the Darling range; he, however, failed to detect any fossils in these supposed Devonian beds. (These are the Desert Sandstones.)

Some doubt seems to have existed relative to the Carboniferous group, to what horizons to refer the coal-bearing strata of the Irwin river, though probably these coals are of Mesozoic age; and Gregory stated that on the Fitzgerald river "a true seam of coal had not been found," the known bed being horizontal and resting unconformably upon the edges of highly elevated Carboniferous Shales, and containing distinct fragments of wood and infusible resin. In a note by the Editor of the Quart. Journ. Geol. Soc. the following genera are said to occur in the collection brought from Western Australia by Mr. Gregory, and which determined these lower beds to be Upper Palæozoic :—*Spirifera*, *Productus*, *Pleurotomaria*, *Nautilus*, *Cyathophyllum*, *Encrinital stems*, being Carboniferous fossils, with coal, from Irwin River.

In 1861 the Rev. W. B. Clarke † also briefly traced the researches which brought to light the position of certain plants in the coal-bearing beds of Australia, stating that Mr. Selwyn (Director of the Geological Survey of Victoria) had recognized in Eastern Victoria "true Carboniferous plants," and that the same author had stated that the fossils of the Tasmanian coal-bearing beds are nearly all Carboniferous or Devonian forms. So with New South Wales, in which colony Mr. Clarke states that the plants said to be "Jurassic" occur associated with a Palæozoic fish, *Urosthenes australis*, Ag.

In the new colony of Queensland, associated with "calcareous beds holding abundance of Carboniferous and Devonian zoological forms, occur shales and fine calcareous grits charged with plants."

Mention is made by Mr. Clarke of some sinkings at Stony Creek, Maitland, by Mr. B. Russell, in which were found *Pachydomi*, *Spiriferæ*, *Orthoceratidæ*, *Conulariæ*, *Asteriadæ*, &c., thus demonstrating in that area the presence of Palæozoic rocks and associated genera of fossils.

* Quart. Journ. Geol. Soc. vol. xvii. p. 475, 1861. † *Ibid.* p. 354.

In 1862 * Mr. Clarke again notices what he believes to be a Permian fauna in Eastern Australia, between the Balonne and Maranoa rivers (Queensland). They were referred by Professor M'Coy to beds " not younger than the base of the Great Oolite, and not older than the base of the Trias." M'Coy enumerated thirty distinct forms from Wollumbilla Creek, the river Amby, and a tract on Fitzroy Downs†. To what age these may all belong is doubtful; Prof. M'Coy, however, believed then that the Wollumbilla fossils were the marine representatives of the so-called Jurassic coal-beds of New South Wales. Mr. Clarke also submitted to Prof. M'Coy some mollusca from the Mantuan Downs, 200 miles north of Wollumbilla (which were pronounced to be of Permian age—Magnesian Limestone), a form allied to *Aulosteges* or *Strophalosia*, and *Productus calva*. The occurrence of Permian strata has not been confirmed in Australia by subsequent observers; and the same may be said of the Trias.

Prof. M'Coy, in 1866, was the first to announce with certainty the discovery of Cretaceous fossils in Australia, from Flinders River, base of Walker's Table Mountains‡. Gregory having previously doubtfully indicated such a group of fossils, M'Coy described three species, two *Inocerami* (*I. Carsoni* and *I. Sutherlandi*) and one Ammonite (*A. Flindersi*). The last-named species, I think, I have detected in Mr. Daintree's collection from Hughenden Station. M'Coy, unfortunately, does not give any figures. I have named this Ammonite after Mr. T. L. Mitchell, and referred it for affinity to *A. Beudanti*, D'Orb.; my name may have to give way to M'Coy's upon comparison with and reference to the original shell in Victoria. *Inoceramus Carsoni*, M'Coy, and *I. Sutherlandi*, M'Coy, may be in the Daintree series; but descriptions of such variable shells as the *Inocerami*, without figures, render identification almost impossible.

In 1867 the Rev. W. B. Clarke also communicated to the Society his paper upon the " Marine fossiliferous Secondary Formations in Australia." §

The author stated that up to the year 1860 no deposit of Secondary age had been demonstrated in Eastern Australia, although Belemnites and a few other fossils belonging to a Lower Secondary formation had been found on the Maranoa river in West Queensland.

The series then under consideration from Wollumbilla, north of the Condamine river, were not exhibited at the International Exhibition in 1862, owing to delay in transit; they were, however, subsequently placed in the hands of Mr. Charles Moore, F.G.S., of Bath, for the purpose of description; that gentleman, in the year 1870, prepared for the Society an elaborate paper describing all the new species, and notes accompanying them. Mr. Moore, in 1862 (previously), met accidentally with a collection of fossils in Somerset-

* Quart. Journ. Geol. Soc. vol. xviii. p. 244. † *Ibid.* pp. 245, 246.

‡ Trans. Royal Soc. Victoria, vol. vii. p. 49.

§ Quart. Journ. Geol. Soc. vol. xxiii. p. 7.

shire*, sent from Western Australia by a Mr. Clifton, probably from Mr. Gregory's Moresby-range series. Mr. Moore determined between fifty and sixty species from the collection, and placed them upon the horizon of the Lias and Lower Oolite of Britain.

Subsequently, in 1863 and 1864, the Rev. W. B. Clarke received other fossils from a locality 15° N. of Champion Bay, probably from near the Moresby Range; the Palæontological facies of these was strikingly representative of early Secondary, Oolitic, or Liassic age, as determined by such forms as *Ostrea Marshii, Ammonites Moorei, Avicula Münsteri, Belemnites canaliculatus,* &c. It would thus appear, then, that the Moresby range was a highly typical locality for the Jurassic deposits of Western Australia.

These disjointed notices, from good and reliable observers, are so many facts tending to show how widely the Lower Secondary rocks must have spread over the Australian continent, and also what extreme denudation they must have suffered during, perhaps, comparatively modern times. Mr. Moore's paper descriptive of the series from Moresby Range has been the means of drawing much attention to the distribution of life through these remarkable rocks, so slightly exposed vertically, over the great plains of Australia.

Mr. Moore, in 1869, in his important paper (published in 1870†) upon "Australian Mesozoic Geology and Palæontology," did great service in pioneering by venturing to describe and correlate the Secondary fossils sent to him for determination; he attributes to Mr. Clifton the credit of having had in his possession the earliest evidence of the presence of Mesozoic fossils on the Australian continent. That part of Mr. Moore's paper devoted to the Queensland Mesozoic fossils, *loc. cit.* pp. 232–259, is highly important to the question of distribution of the Secondary fossils through the colony; and the list of organic remains at pp. 239–40 shadows forth what we may expect when the rocks are thoroughly searched. He has added more to our definite knowledge of the Secondary organic forms of Australia than any other writer.

The only other addition of importance to our knowledge of the Secondary fauna of Australia, prior to Mr. Moore's paper, was Prof. M'Coy's notice and description of a portion of an *Ichthyosaurus* (*I. australis*), supposed by him to be from the Lower Lias, although this was not clearly ascertained. Prof. M'Coy also, in 1866 (Trans. Royal Soc. of Victoria, vol. vii. pp. 49–51, 1866), in an abstract of a paper "On the Discovery of Cretaceous Fossils in Australia," mentions receiving from the western bank of the Flinders river, at the base of Walker's Table Mountains, lat. 21° 13′, long. 143°, through Messrs. Sutherland and Carson, a small collection of geological specimens; "this enabled Prof. M'Coy to announce for the first time, *with certainty*, the existence of the Cretaceous formations in Australia."

* Sent to Mr. Sanford, probably from Sparks Bay or Champion Bay. (Worcestershire in Mr. Clark's paper.)

† Quart. Journ. Geol. Soc. vol. xxvi. pp. 226–259, accompanied by nine plates.

It would seem, then, that Mr. Moore has clearly determined the presence of a Middle and Upper Lias fauna; *i. e.* the Australian Lower Secondary rocks contain fossils almost identical in facies with those of the Lias of Europe and N. E. India, or which, homotaxially, may be of, or represent, the same age.

It is, however, to be regretted that his specimens were not obtained *in situ*, instead of from drifted materials; for nothing is known of the beds or sections from which the Wollumbilla fossils originally came. It is not a little singular, however, that Mr. Moore recognized twenty species as common to England and Western Australia *. Amongst the Cephalopoda are five species of Ammonites, one Nautilus, and one Belemnite, chiefly from the Upper Lias and Lower Oolite; the remaining thirteen species of Lamellibranchiata, with two exceptions, are also of Lower Oolitic age. Mr. Moore believes that many others common to the two countries occur; but their worn and eroded state prevented reliable identification.

Queensland.

I have now to add some new facts relative to the distribution of life through the North Queensland rocks, from which Mr. Daintree has obtained a more general series of Plantæ, Mollusca, and Cœlenterata, mostly new, and ranging from the Silurian to the Tertiary deposits—the Devonian, Carboniferous, and Cretaceous being well represented.

Mr. Daintree's specimens were mostly obtained *in situ*—but nevertheless nearly all occur in the form of casts, arising doubtless from the solvent action of water by percolation and oxidation, as they are not abraded or water-worn; nor, from their condition, could they have been much exposed to the atmosphere.

It is therefore to be regretted that so few of our specimens possess the outer shell, so essential to the true diagnosis and differentiation of species. It is, however, felt that if all the Australian fossils are to be rejected, or no attempt made to determine them, little or no stimulus will be given to the exploration of those vast and widely spread fossiliferous regions and rock-masses which occupy so extensive an area in Queensland and other parts of Australia.

To figure them also *without* some individual description and indications of affinities with well-known forms would tend to mislead. I have therefore been bold enough to do both, viz. give the best figure possible and the clearest description I could with the materials composing the collection at my command. Doubtless the time will come when better and more perfect specimens will be found; the task of identification will then be much easier than that which, at the request of Mr. Daintree, I have undertaken.

The succession of the Australian rocks in time, as proved and established by stratigraphical position, sequence, or succession, is

* Quart. Journ. Geol. Soc. vol. xxvi. p. 231.

supported by palæontological research; and there cannot now be any doubt that the Broken-River Limestone beds, containing *Favosites* &c. &c., are the lowest fossiliferous deposits in the Queensland area, and their age is undoubtedly Lower Devonian or "Siluro-Devonian." These are succeeded by the Gympie group, a higher series, with the Star-River and Mount-Wyatt beds succeeding, rich in *Lepidodendra* and *Spiriferæ*. These Devonian rocks yield generally *Lepidodendron*, *Leptophlœum*, *Productus*, *Spirifera*, &c. &c.—indeed, possess a fauna and flora closely allied to that of Canada, of the same age. The Carboniferous rocks of the Don river, which succeed unconformably, are also of the same relative age as the British and European series; no less than ten species are known to be common to the two countries. The genus *Glossopteris* is abundantly distributed through the upper beds of this group at Bowen River, Roper Creek, and Dawson River; and research has shown that this plant does not range higher in the Australian rocks. Associated with *Glossopteris* there occurs an extensive fauna of Mollusca, especially Brachiopoda.

It is doubtful if true Permian and Trias exist or are represented on the Australian continent. Neither organic remains nor rocks in position afford any true clue to the occurrence of these deposits, which are so widely spread in Europe, Africa, and India.

The Secondary rocks of Queensland also exhibit the most complete unconformity to the Palæozoic below; the rocks known *in situ* to thus overlie the Carboniferous are the Lower Oolitic series of Gordon Downs, Wollumbilla, Burrum, and Tivoli. The upper members of the Oolites are freshwater and estuarine beds, and form the southern Coal-field of Queensland, characterized by the abundant presence of *Tæniopteris* &c. &c.* and but few Mollusca, indeed a small fauna so far as is yet known. Mr. C. Moore, through specimens obtained at Wollumbilla (though not *in situ*) clearly revealed and proved the presence of Lower Lias, Oolite, and Oxford-Clay fossils in that area. At Pelican Creek and Gordon Downs we clearly possess the marine Oolitic rocks in position; but the fossils are in an extremely bad state of preservation, and but few in species.

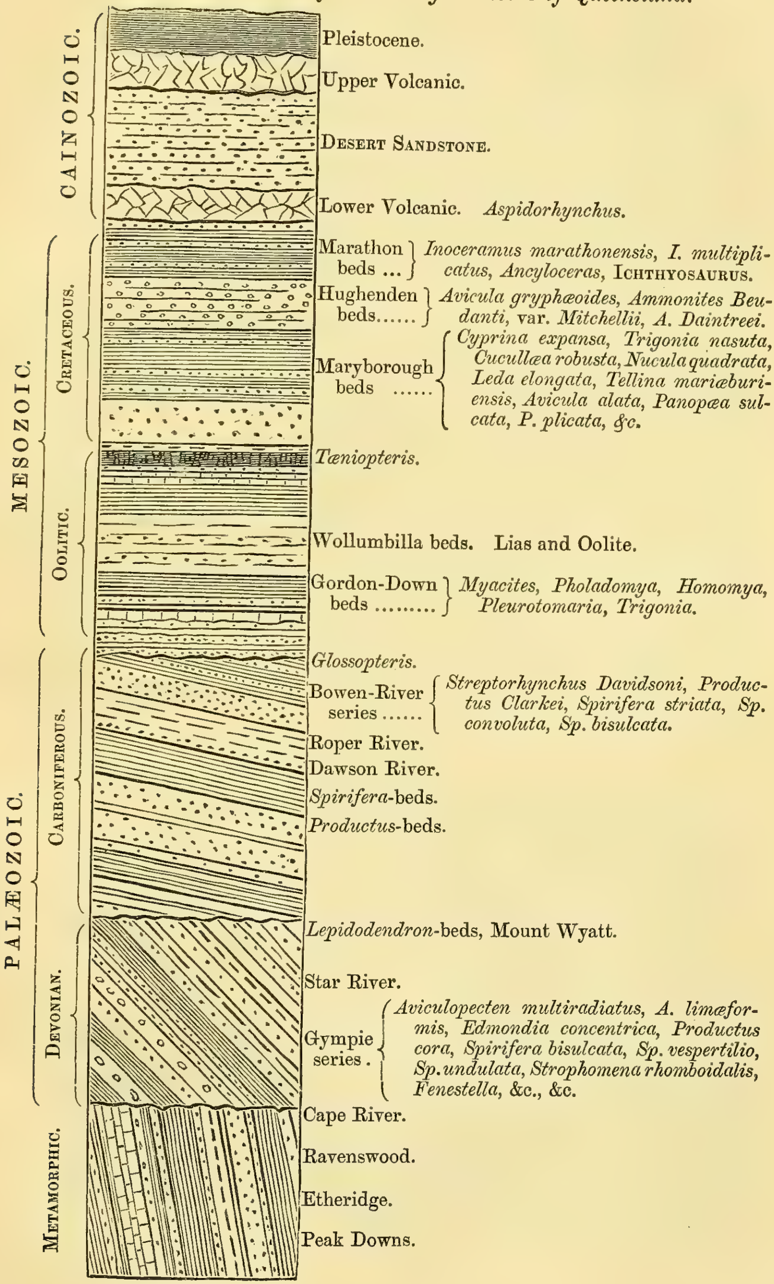
Succeeding these are the Coal-bearing fresh-water beds of Tivoli and Burrum, containing *Tæniopteris*, which are the highest of the Lower Secondary or Mesozoic series of Queensland.

The Upper Secondary (Cretaceous) series of Maryborough, Hughenden, Marathon, and O'Connel Creek may succeed each other in the order here given; and, from the fossil evidence, I am disposed to place them in this order of superposition or time, believing that the Maryborough beds are the lowest, the Hughenden, Marathon, and Flinders beds succeeding them.

Dolerites or augitic Trap rocks, or "the Lower Volcanic Series," close the Cretaceous period, and are succeeded by the Desert Sandstone, which occupies an immensely extended area over Queensland. Whether this series is estuarine or freshwater in its

* Wealden ?

Fig. 1.—*Succession of the Stratified Rocks of Queensland.*



origin is doubtful; it was probably the latter, no marine organism ever having been found in it: so vast an estuarine deposit would, I must believe, under any change of level exhibit occasional fossils of estuarine and brackish water or semimarine types. The close of the Desert Sandstone is marked by a recurrence of Dolerite Trap rocks, or "Upper Volcanic," similar in character to the Lower, or those which underlie the Sandstone.

The above condensed stratigraphical sequence of the Queensland formations may aid those who refer to the Palæontological Appendix only; their pure geology is discussed at length by the Agent-General for Queensland (Mr. Daintree) in his extended paper.

I purposed constructing a distribution-table for the organic remains of Queensland, West Australia, and Victoria &c., but, after much research, determined for the present to abandon this until more definite materials or data for time-range could be obtained. Much has to be done in definitely placing together the palæozoic species; and as more materials are about to arrive in England, it is better to defer this attempt for the present.

Mr. Daintree has placed the whole collection at my disposal, and allowed me to select those specimens most typical or sufficiently characteristic and well marked to enable me to draw up some definite characters, and refer them to known forms where possible. The Plantæ receive the same attention, through Mr. Carruthers, F.R.S.; and it is hoped that the collection * made by Mr. Daintree and others, and now figured, will be instrumental in leading to further extended research through the sedimentary rocks of Australia generally.

Palæozoic.

Devonian.

Aviculopecten ? limæformis, Morris, sp. Pl. XIV. fig. 1.

Ref. Strzelecki's Phys. Descr. of New South Wales and Van Diemen's Land, 1845, t. 13. fig. 1.

I refer this shell to the *Pecten* (*Aviculopecten*) *limæformis*, Morris, described and figured by him in Strzelecki's 'New South Wales and Van Diemen's Land,' p. 277, t. 13. fig. 1.

Of this fine shell we have only a mould of about one half of the right valve; it is nevertheless sufficient to allow me to refer

* The ship ('Queen of the Thames') which conveyed both Mr. Daintree and his large collection of minerals and fossils from Melbourne, was wrecked off the east coast of Africa, near the village of Bredarsdorp; and, as may be supposed, neither minerals nor fossils were much improved by their *long* submergence prior to recovery. The labour and anxiety of many years' research to establish the age and nature of the stratified rocks of Queensland was then nearly lost; and but for the fortunate position of the ship near the shore, fresh collections must have been made to elucidate the physical character and structure of the Colony. The importance and value of such research as that carried out by Mr. Daintree is detailed in his elaborate paper on the General Geology of Queensland

it to the above species. Shell inequilateral or oblique, slightly convex near the umbonal region or beak; the ribs are also irregular and wavy, about 35 in number, and all meet near the umbo; lines of growth obscurely wrinkled; ears small, radiated, and coarsely wrinkled. Prof. Morris does not state the dimensions of his shell; proportionately our single specimen agrees with his, but apparently is individually larger.

I insert the original description by Prof. Morris:—"Shell suborbicular inæquilateral, most convex towards the beak; rays numerous, irregular, approximate near the beak; ears rather small, wrinkled. *Loc.* Eastern Marshes, Van Diemen's Land."

Loc. Gympie. *Form.* Devonian.

Aviculopecten? imbricatus, Ether. Plate XIV. fig. 2.

An impression only, and that of the inner surface, of one valve of this singular and doubtful shell occurs. Our figure is taken from a gutta-percha cast of the impression left; and its peculiarity induces me to figure and notice it, in the hope of receiving perfect specimens. That it belongs to the Asiphonida I do not doubt, and, I believe, to one of the Aviculidæ. The umbonal region is certainly not complete; and therefore no true conclusion can be arrived at relative to the nature of the ears and hinge-line of the perfect shell.

Shell inequilateral, and possessing twenty-two ribs, the ends or extremities of which imbricate or overlap in the cast; there appears to be, or to have been, a space between the end of each rib at its extremity, or along the ventral margin; faint longitudinal markings run down each of the ribs, following their course. Many of our *Limæ* possess bent and folded ribs (Ex. *L. rustica*); but their peculiar arrangement in our shell is different from that in any known *Lima*.

Loc. Gympie. *Form.* Devonian.

Aviculopecten multiradiatus, Ether. Plate XIII. fig. 1.

Shell nearly equilateral, orbicular, depressed, slightly convex, with about sixty well-defined equidistant sharp ribs, all meeting at the umbo; these ribs appear to have been sharply elevated and plain; ears not seen; lines of growth well defined.

Figure reduced one fourth.

Loc. Gympie. *Form.* Devonian.

Obs. This shell resembles *Av. planoradiatus*, M'Coy, both in form and in the nature of the ribs; our shell, however, has the edges of the ribs sharp, instead of being flattened, and is not so convex a shell as *A. planoradiatus.* It has also affinity with *Pecten squamuliferus*, Morris, from Mount Wellington, Van Diemen's Land*; I cannot, however, clearly determine the presence of imbricated scales upon the ribs; and unfortunately we have no "ears" left to correlate with Prof. Morris's species: it may also be compared with the *Aviculopecten docens*, M'Coy, Brit. Pal. Foss. t. 3. figs. 6 & 7. Our shell also possesses about the same number of ribs.

* Strzelecki, Phys. Desc. N. S. Wales and Van Diemen's Land, p. 278, t. 14, f. 1.

Edmondia concentrica, Ether. Pl. XIII. fig. 2.

Shell oblong, apparently equivalve, postero-dorsal margin convex, antero-dorsal steeply inclined from umbo to anterior slope; umbones small, indistinct; surface with numerous concentric and imbricated lines of growth in band-like zones; posterior side acutely rounded; anterior obtusely rounded or truncated.

Obs. *Edmondia* is a convenient genus to which we may refer these Myacitiform shells, especially when no true shell-structure occurs upon them; and in this genus I place the above shell. We are prevented from seeing the large oblique cartilage-plates beneath the umbones, owing to the matrix. The genus *Sanguinolites*, M'Coy (in part), receives some Edmondiiform shells; but the general form and aspect of our specimen precludes it. I figure it, like many other forms, to draw the attention of Australian geologists to the Lamellibranchiata of the Palæozoic rocks of Queensland and elsewhere through the colony, in the hope that search may be made for more perfect specimens.

Loc. Gympie. *Form.* Devonian.

Edmondia obovata, Ether. Pl. XIII. fig. 3.

Shell ovate, anterior margin convex, or nearly circular; posterior margin slightly truncated; hinge-line nearly straight; umbones small, close to anterior side; ventral margin almost parallel with dorsal; outer shell wanting, but appears to have been concentrically banded.

Obs. I place this shell in the above genus, although it may be a *Myacites*; but the want of outer shell to show whether granulated or not, prevents our determining this point. *Pullastra ovalis*, M'Coy, and *Edmondia*? *compressa*, M'Coy, from the Carboniferous series of Ireland, much resemble this species in form, especially the former; our shell is from the "fossiliferous greenstone" of Beehive Reef, Gympie, and, from the associated Mollusca, is probably of Devonian age.

Loc. Gympie. *Form.* Devonian.

Productus cora, D'Orb. Pl. XV. figs. 1 & 2.

Ref. Paléont. du Voyage dans l'Amérique Méridionale, t. 5. figs. 8–10; Dav. Monog. Brit. Carb. Brachiop. (Pal. Soc.), p. 148, t. 36. fig. 4, t. 42. fig. 9.

This well-known British and European Carboniferous shell has great range both in time and space, occurring in India, America, Russia, Belgium, and Great Britain, and is now, for the first time, recognized in Australia. In Britain we do not know this shell in our Devonian series. Although described by D'Orbigny under this name, by De Koninck as *Productus cornoides*, by M'Coy as *P. corrugata*, and by M'Chesney as *P. pileiformis*, they are nevertheless all one species. Our shell was evidently very thin and fragile, with a gibbous ventral valve, the surface covered with straight, wavy, or flexuous longitudinal thread-like striæ or ribs, and few spines.

The dorsal valve (fig. 2) shows the rugose undulating folds or wrinkles at the cardinal angles.

We fail to see the concentric lines crossing the ribs on our examples, owing to their condition; and the places of former spines are faintly traceable.

It is not a little singular that this shell, so common in the Carboniferous rocks of Great Britain and not known with us as a Devonian form, is yet associated with *Lepidodendra* in the Devonian rocks of Queensland, to which strata the genus *Lepidodendron* is there confined, and where homotaxially it seems to have preceded its appearance in Europe; associated also with *P. cora* we have plant-remains, which are noticed by Mr. Carruthers in a second appendix to Mr. Daintree's paper.

Loc. Gympie, New-Caledonia Reef. *Form.* Devonian.

SPIRIFERA BISULCATA, Sow., var. ACUTA. Pl. XVI. fig. 1.

I can only refer this fragment of a *Spirifera* to one of the many forms assumed by the variable species *S. bisulcata*, Sow. (*S. trigonalis*, Mart.). One chief character (the mesial fold) is wanting in our specimen; but in all other respects it agrees with many British and European forms. *S. bisulcata* is not a British Devonian species; its place seems taken by the representative shell *S. undulata*, Röm., which seems to be as abundantly distributed through the Devonian rocks in Queensland as in England and Germany; and the cardinal angles of our shell are more acute than in many of the variations assumed by European forms. The varietal name *acuta* will serve to distinguish it from those possessing more tumid cardinal angles; it possesses also sharp ribs.

Some Irish and Scotch forms of *S. striata* resemble our shell, but possess usually much finer and more numerous ribs. The undulation of the ventral margin, especially the mesial fold, is usually much more pronounced.

Loc. Gympie. *Form.* Devonian.

SPIRIFERA VESPERTILIO, Sow. Pl. XVI. fig. 2.

Ref. Pal. Shells of Van Diemen's Land, Appendix to Darwin's Geol. Obs. on Volc. Islands &c., p. 160, 1844*.

I cannot do other than refer this fragmentary *Spirifera* to the above species. It has not the number of ribs described by Sowerby; but their angular, imbricated, or fimbriated condition, the width of the mesial fold or ridge, and the pointed beak, with the transversely fusiform shape of the one valve, are sufficient to warrant my retaining this name for the specimen from Gympie.

Many *Spiriferæ* in the British rocks, belonging to this fusiform group, much resemble our shell in general aspect, especially the varieties of *S. convoluta*, Phill.; but none of our British or European shells possesses the aspect of the valve under notice; five or six rows

* Also, Strzelecki, Phys. Desc. New South Wales and Van Diemen's Land, p. 282, t. 17. figs. 1–3.

of acutely angular imbrications are distinguishable upon the mesial fold, and traceable along the attenuated lateral wings of the cardinal angles. It is impossible to state what was the nature of the hinge-area and its sides, and whether parallel or not. I figure the specimen as having an important bearing upon the determination and distribution of these fusiform *Spiriferæ* on the Australian continent and adjacent islands, as well as adjoining lands.

Loc. Gympie goldfield. *Form.* Devonian.

SPIRIFERA DUBIA, Ether. Pl. XVI. fig. 6.

Shell transversely semicircular; hinge-line nearly as long as the width of the shell; cardinal angles gently rounded; mesial fold having many small ribs, and wide at ventral border of shell; eight or nine ribs occur on each side of the mesial fold upon the cardinal angle or lateral portion of the shell. It is evident that many small ribs occurred upon the mesial fold, and some of the ribs upon the lateral areas bifurcated as they approached the ventral margin.

This shell resembles some forms of *Spirifera undulata*; but the ribs are finer than in normal forms of that species; the ribbed mesial fold and bifurcating lateral ribs are essential points of difference. Not having any outer shell, we have no means of determining any markings upon the valves; but it differs from known species of *Spirifera*. I know of no species, either Devonian or Carboniferous, to which the above shell can be referred, the rounded cardinal angles and almost semicircular dorsal valve distinguishing it from every known form.

Loc. Gympie. *Form.* Devonian.

SPIRIFERA UNDIFERA, var. UNDULATA, F. Röm. Pl. XVI. figs. 3, 4, 5.

Ref. Rhein. Uebergangsgeb. p. 70, t. 4. fig. 5; Dav. Monog. Brit. Dev. Brach., Pal. Soc. p. 37, t. 7. figs. 11–14.

This well-known variety of *Spirifera undifera* needs scarcely any description here, Römer having described it in his 'Rheinische Uebergangsgeb.,' p. 70, t. 4. fig. 5, and Schlotheim having previously described *S. curvatus*, of which our shell is a variety. Again the *S. undifera* of Schnur, 'Dunker's Palæontographica,' vol. ii. p. 204, t. 34. figs. 9, 9*h*, appears to be closely allied to our Queensland shell. Mr. Davidson, in his 'Monograph upon the Devonian Brachiopoda,' Pal. Soc. p. 37, t. 7. figs. 11–14, figures one variety, *S. undulata*, which appears to be scarcely distinguishable from the Queensland form. Comparison with Schnur's figures of *S. undifera* and *S. undulata*, Röm., leads me to consider them varieties or modifications of the same shell differentiated according to circumstances during life.

The Queensland specimens differ little amongst themselves, all having the well-marked mesial fold in the ventral valve and eight or ten ribs on either side; the hinge-line is shorter than the width of the shell, and the cardinal angles are rounded. The beak in dorsal valve incurved; there are faint tracings of the concentric ridges or folds; but, owing to all the specimens being casts, the more delicate markings cannot be determined. The distribution of this species is nearly world-wide, being cosmopolitan or ubiquitous in every sense of the word. Strzelecki, in his 'Physical Description of New South Wales and Van Diemen's Land,' does not seem to have met with it there; but a representative shell, *S. tasmaniensis*, Morris, occurs in rocks of the same age: in many respects this shell resembles our Queensland species; but the hinge-line is wider, and the cardinal angles are less rounded.

Loc. Gympie. *Form.* Devonian.

STROPHOMENA RHOMBOIDALIS, var. ANALOGA, Phill. Plate XVI. fig. 7.

Ref. Producta analoga, Phill. Geol. Yorks. vol. ii. p. 215, t. 7. fig. 10; Dav. Monog. Brit. Carb. Brach., Pal. Soc. p. 119, t. 28. fig. 2.

This shell occurs in the Silurian, Devonian, and Carboniferous rocks over large areas of the globe, and abundantly in the Devonian series of the Gympie gold-bearing beds in Queensland. Our shell differs in no respect from the well-known forms described by Wahlenberg, Sowerby, Phillips, and De Koninck. Mr. Davidson, in his great work upon the Palæozoic Brachiopoda, in the Mem. Pal. Soc., has in each Monograph described and figured this ubiquitous species. *Producta depressa*, Sow. M. C. t. 459. fig. 3, *Leptæna depressa*, Kon., *Producta analoga*, Phil. (*loc. cit.*), are all one and the same species. I have submitted the specimen to Mr. Davidson, who recognized it to be the above species without doubt.

Loc. Gympie goldfield. *Form.* Devonian.

STROPHOMENA RHOMBOIDALIS, var. ANALOGA, Phill. Plate XV. figs. 3 & 5.

Reference is made to this widely distributed shell above. It is of importance to figure this species from this rock and locality, from its occurrence with certain other fossils, and also as bearing upon the question of associated forms of life in rocks yielding gold at Lady-Mary Reef, Gympie diggings.

Loc. Lady-Mary Reef, Gympie goldfield. *Form.* Devonian.

SPIRIFERA UNDIFERA, var. UNDULATA, Röm. Plate XV. fig. 4.

Ref. Loc. cit.

This shell has been noticed on the preceding page, and more perfect specimens figured on Plate XVI. figs. 3, 4, 5. This shell, like *Strophomena rhomboidalis*, is associated with the auriferous deposits at Lady-Mary Reef, Gympie. Nearly all the rock-specimens contain *Producti*, and *Strophomena rhomboidalis*, var. *analoga*, associated with the above shell and abundantly distributed.

Loc. Lady-Mary Reef, Gympie goldfield. *Form.* Devonian.

PLEUROTOMARIA CARINATA, Sow. Pl. XV. fig. 6.

Ref. Min. Conch. t. 640. fig. 3; Phill. Geol. York. vol. ii. t. 15. fig. 1.

Shell depressed, composed of three or four whorls; base flat; body-whorl large, expanded, the two upper whorls (in our specimen) distorted; umbilicus not seen; shape of aperture doubtful; no shell-structure left.

Obs. I can scarcely detect any difference between the form and habit of this shell and those of *Pleurotomaria carinata*, Sow. Its size is greater; but unfortunately the loss of the outer shell prevents our seeing the band or slit at the edge of the whorl, in the absence of which it might be referred to *Raphistoma* or *Platyschisma*; it is not, however, sufficiently depressed to be referred to the former genus.

The species of this genus, unless well defined, are at all times most difficult to determine; in the above case I am not justified in proposing a new name, and therefore refer it to Sowerby's *P. carinata*, which it *very* closely resembles.

Loc. Gympie. *Form.* Devonian.

Euomphalus, sp.?

Owing to the fragmentary condition of the few specimens in the collection, referred to this genus, we can only state its occurrence in the Devonian rocks of the Gympie goldfield. They are associated with *Favosites*, *Stenopora*, &c.

Loc. Gympie. *Form.* Devonian.

Fenestella fossula, Lonsdale. Pl. XXV. fig. 1.

Ref. Strzelecki's Phys. Desc. of New South Wales & Van Diemen's Land, p. 269, t. 9. figs. 2 *a*, *b*.

Form of polyzoarium not known, probably cup-shaped; our portion is foliaceous; meshes or fenestrules oval, small, densely arranged upon the expanded cœnœcium or polypidom; transverse processes or bars non-cellular.

These unsatisfactory specimens of *Fenestella* I refer to Lonsdale's species *F. fossula*.

Obs. No good characters are left for determination; the transverse processes or bars, and the fenestrules, are so obscure that any attempt to give definite characters would mislead; it so closely resembles *F. fossula*, from Mount Wellington, Van Diemen's Land, and St. Patrick's Plains, New South Wales, that I feel obliged to refer it to that form; any additional species would only multiply names. I had, however, proposed the name *F. densa* for our Queensland specimen.

The original habit was probably infundibuliform or cup-shaped; but whether the bars were rectangularly dichotomous, with oval meshes, cannot be distinctly made out.

Loc. Gympie, Smithfield Reef. *Form.* Devonian.

Ceriopora? laxa, Ether. Pl. XXV. figs. 2, 2*a*.

Polyzoarium branching, branches bifurcating twice or thrice, subcylindrical or compressed, pores small, apparently round, and equal, opening upwards; whether the cell-openings inclined at any particular angle to the axis of the branches I cannot determine. Only one specimen has occurred to us, associated with the densely reticulated cœnœcium of *Fenestella fossula*, Lonsdale.

Obs. The habit of this species resembles that of the plant *Lycopodium clavatum.* It has affinity with *Ceriopora* (*Favosites*) *serialis*, Portl., from the Carboniferous rock of Hook Point, south of Ireland, to which I was inclined to refer it; but the cœnœcium is neither so densely nor so regularly covered with cell-openings as in that species although in habit and bifurcation it is similar.

Loc. Gympie. *Form.* Devonian.

Carboniferous.

STREPTORHYNCHUS DAVIDSONI, Ether. Pl. XVII. fig. 1.

Shell nearly semicircular, hinge-line short, not so wide as greatest width of shell; area small, cardinal angles rounded; ventral valve nearly flat, or slightly convex, with numerous closely set costæ (not so numerous as those upon the surface of the dorsal valve).

Dorsal valve convex, and strongly ribbed, ribs about twenty-five in number, rounded and depressed, having smaller ribs between each pair of larger ones, the interspaces delicately marked by concentric wavy lines, or striæ, which pass over the costæ, or ribs.

Obs. This shell differs essentially from the British species of *Streptorhynchi* in the coarseness of its ribbing, or costæ, in the more depressed and truncated cardinal angles, and the more pronounced or acute umbonal region. We have no interior for comparison, the specimen described being the only one in our possession; but it fortunately possesses some of the outer shell.

This subgenus of *Strophomena* is seldom well preserved, the characters being generally very indistinct. Only one species (*Sp. crenistria*), with three or four varietal forms, is known in Europe. From their extreme variation the forms of *Streptorhynchus* have received numerous specific names, now all referable to one. Mr. Davidson, F.R.S., has examined the above shell, and cannot refer it to any known form of *Streptorhynchus.* I therefore, after careful examination, hesitate not to name it after the distinguished naturalist and Brachiopodist whose labours to unravel and elucidate the structure and history of this difficult group have surpassed those of all other writers, and who in readiness to assist those who desire information and knowledge is surpassed by none.

Loc. Bowen River and Peak Downs. *Form.* Carboniferous.

STROPHOMENA RHOMBOIDALIS, var. ANALOGA, Phill. Pl. XVIII. fig. 1.

We have noticed this shell, under the Devonian group, from the Gympie goldfield (pp. 330, 331).

Loc. Head of Don River. *Form.* Carboniferous.

PRODUCTUS LONGISPINUS, Sow. Plate XVIII. fig. 9.

Ref. Min. Conch. vol. i. p. 154, t. 68. fig. 1; Dav. Mon. Brit. Carb. Brach., Pal. Soc. p. 154, t. 35. figs. 5–17.

I cannot detect any difference between this one specimen and the British species; and Mr. Davidson refers it also to *P. longispinus*; our shell is the inner cast of the dorsal valve.

This common and widely spread shell is the most variable of the *Producti*, and seldom attains a larger size than our specimen, which is a cast of the interior of the dorsal valve. It is known in the Carboniferous Limestone of the Punjaub in India, Carro Creek in Tasmania, Bolivia, Russia, and Belgium, and everywhere in Britain; we now, for the first time, record it from Queensland.

Loc. Don River. *Form.* Carboniferous.

Productus Clarkei, Ether. Plate XVII. figs. 2, 2 *a*, 2 *b*.

Shell ovate, nearly as wide as long, hinge-line short, cardinal angles rounded; the beak appears to have been moderately developed; the small or dorsal valve nearly flat, and following the course of the ventral valve, which is convex, or gibbous; beak, or umbo, moderately developed, incurved; surface of shell covered with fine vertical wavy lines, projecting from which are numerous slender spines.

Obs. Affinities:—The ventral valve of this shell much resembles in shape certain forms of *P. scalenoides*; but the dorsal valve in our species is much flatter than in *P. scalenoides*, or, indeed, any other known *Productus*. The flat or dorsal valve is furrowed by numerous concentric lines of growth, which apparently possessed spines, points of attachment for which still remain.

Externally our shell is also allied to *P. muricatus*, Phill., but is much larger; and many forms of *P. Youngianus* may at first sight be mistaken for it; the latter shell, however, is deeper, and the umbo more incurved than in *P. Clarkei*.

Loc. Bowen River. *Form.* Carboniferous.

No one on the Australian continent has done so much to further our knowledge of its physical structure as the Rev. W. B. Clarke, M.A., F.G.S., &c.; to him both colonists and geologists are deeply indebted for the patient and determined labour with which he has worked out the auriferous deposits and fossil contents of the Australian rocks. I therefore associate his name with this shell, which seems abundant.

Productus or Strophalosia. Pl. XVIII. figs. 4, 4 *a*.

I am in doubt about assigning even the generic name to this shell. That it belongs to the Productidæ is evident; but whether to the genus *Productus* or *Strophalosia* it is difficult to determine. We have the dorsal and ventral valves of two different individuals; but none of the outer shell remains, only some of the inner pearly concentric coats. The dorsal valve resembles that of *P. scabriculus*, especially in the peculiar arrangement of its spines. It occurs in a pale grey limestone composed chiefly of the crowded and broken remains of the species.

Loc. Weelwandangela Creek, Noyoa River. *Form.* Carboniferous.

Spirifera striata (Martin). Pl. XVII. fig. 5.

Ref. Pet. Derb. t. 23; Dav. Mon. Carb. Brach., Pal. Soc. p. 19, t. 2. figs. 12–21, t. 3. figs. 2–6.

This shell has all the characters of our common British species.

The mesial fold is not so well defined as in the typical *Sp. striata*; and some transverse forms of *Sp. bisulcata* assume this shape. We may, however, confidently refer it to the above shell, or one of its many varieties.

This most variable and widely distributed species of the genus *Spirifera* appears to be not uncommon, as I have been given to understand that individuals of the species are abundant in the Bowen-River series. This shell is typical of the Carboniferous rocks in every region of the globe where deposits of this age occur.

The hinge-line is as long as the greatest width of the shell, and the cardinal angles somewhat acute; the ribs on the surface of our shell are finer than in most specimens; it resembles some Yorkshire as well as American forms; but we have had no opportunity of comparing it with Russian specimens.

Loc. Bowen River, Peak Downs. *Form.* Carboniferous.

Spirifera convoluta? Phill. Pl. XVII. fig. 3.

Ref. Geol. Yorkshire, vol. ii. p. 217, t. 9. fig. 7; Dav. Mon. Brit. Carb. Brach., Pal. Soc. p. 35, t. 5. figs. 2–15.

We may refer this fragment to *Sp. convoluta*; its extreme width and straight hinge-line essentially ally it to this shell; the acute angles at the extremities are lost; still many of our Yorkshire shells strongly resemble this species: the ribs on the mesial fold are also less defined than on most typical forms; it is, however, closely allied to our British species.

We have only a portion of the shell by which to compare it with British and Belgian shells; but the identification cannot, I think, be doubted.

Loc. Bowen River. *Form.* Carboniferous.

Spirifera allied to *S. bisulcata*, Sow. Pl. XVII. fig. 4.

Ref. Min. Conch. t. 492. figs. 1, 2; Dav. Mon. Carb. Brach., Pal. Soc. p. 31, t. 6. figs. 1–19.

The ventral valve only of this shell occurs; and I refer it to one of the many forms of *Sp. bisulcata* as being the nearest; we figure it as an important example from the Carboniferous rocks and for future research. The incurved and approximate beaks are well shown, also the numerous and fine ribs upon both sides of the mesial fold. Unfortunately the cardinal area is not seen, but the complete description of the varieties and forms of this shell by Thomas Davidson, Esq., F.R.S., in his valuable memoir upon the Carboniferous Brachiopoda, Pal. Soc. p. 31, t. 6. figs. 1–19, supplies the want of better specimens.

Our shell possesses scarcely so elongated a hinge-line as most of the forms of this species; but the rounded cardinal extremities, or angles, wide area and incurved beak, as well as the facies, leave little doubt about its alliance. This, like many species of *Spirifera*, is extensively distributed in time and space, especially through the Carboniferous series of Europe.

Loc. Bowen River. *Form.* Carboniferous.

SPIRIFERA allied to *S. striata*, Sow. Pl. XVIII. fig. 8.

So variable a form as the above may have referred to it any species with equally convex valves, a moderately elevated mesial fold, a variable number of radiating ribs, and a straight hinge-line. We fail to recognize the reticulated ornamentation of the outer surface, arising from the want of the perfect outer shell.

We possess only the dorsal valve of this form, and, therefore, are not justified in giving it a varietal name. I figure it amongst other shells &c. occurring in the Don-River Carboniferous rocks. It is said to be abundant in Queensland; I, however, only recognize one valve amongst the Daintree collection. Many varieties of *S. bisulcata*, Sow., especially some forms of the var. *semicircularis*, Phill., also very much resemble our shell. I name these affinities in the hope that attention may be paid to them when better specimens occur; and the works of Davidson, De Koninck, M'Coy, &c. are now, or should be, in the chief Colonial libraries.

Loc. Don River, N. Queensland. *Form.* Carboniferous.

CHONETES CRACOWENSIS, Ether. Pl. XVIII. fig. 2.

The subgenus *Chonetes* seems only to be illustrated by one species; but of this there are many individuals.

Sp. char. Shell transversely oblong or semicircular, wider than long, both valves ornamented with many ribs; hinge-line straight, not so long as the width of the shell, area narrow and parallel—ventral margin convex. Cardinal angles rounded and flattened at their extremities. Ventral valve slightly convex. Dorsal valve nearly flat, or following the curve of the ventral. Beak small, apparently slightly incurved, but not covering the hinge-line. The place of the hinge-spines faintly traceable. The surface of the shell covered by what must have been short and stout spines numerously distributed.

Obs. The species of this genus vary to an immense extent, so much so that they may be almost recognized according to their locality—habitat and bathymetrical conditions, &c., being evidently the cause. This shell resembles *C. hardrensis*, so abundant in the Devonian and Carboniferous rocks of Europe, but differs from the allied British species, *C. Buchiana* and *C. Dalmaniana*. With the latter it has no affinity, the ribs being much finer than in either of them, the spines being more numerous and the hinge-line longer; with the variable *C. hardrensis*, however, it has considerable affinity, especially with Phillips's type form; but the spines are much more numerous, and the cardinal angles more pronounced and flattened. Whether the ribs bifurcated or not I cannot determine.

The abundance of this shell at Cracow Creek, and its differences from other known species, suggest the name I have ventured to give it.

Loc. Cracow Creek. *Form.* Carboniferous.

PLEUROTOMARIA ROTUNDA, Ether. Pl. XVIII. fig. 3.

Shell turbinate or trochiform, with four whorls; apex slightly depressed; aperture suboval or subangular. Whorls completely rounded and concentrically striated with numerous close-set costæ, which are crossed diagonally from the mouth backwards by very fine lines, giving the shell a reticulate appearance*. Base slightly convex. Umbilicus very small or obsolete. Sinus scarcely distinguishable.

This shell appears at first sight to be smooth, the ornamentation being microscopic, yet definite; on a portion only of the shell is there structure remaining. In form, size, and general aspect *P. rotunda* resembles *P. granulata*, De Kon.; but the sculpturing of the shell and the band-like sinus remove it from that species. *P. rotundata*, Phill., in the rotundity of the whorls and other minor points, somewhat resembles it; but our species is much less acute in the spire.

Only one specimen occurs, which is to be regretted.

Loc. Cracow Creek. *Form.* Carboniferous.

Naticopsis? harpæformis, Ether. Pl. XVIII. fig. 6.

Only the body-whorl of this singular little shell is left for our examination, and this only seen in part; but so rare are these shells in the older rocks that we are glad to recognize and figure the smallest fragment.

The only shell in the British Palæozoic rocks approaching this in shape is the *Cylindrites* (*Conus*) *carbonarius*, De Kon.; but the body-whorl in that species is more attenuated, and the suture appears to have been deeper; again, we have no lip exposed, so that the aperture and canal cannot be examined. The summit of the body-whorl is ornamented with thirty or thirty-five nodes or tubercles, each of which occupies the summit of a rib or varice. The upper whorls are lost; they must, however, have been very much depressed. This shell bears resemblance to *Macrocheilus canaliculatus*, M'Coy, and *M. ovalis*, M'Coy, especially the former—through both the body-whorl and what must have been the depressed suture to *Natica meridionalis*, Phil. (Pal. Foss. Dev. and Cornw. t. 36, f. 173), and also *Macrocheilus*, Phil. *loc. cit.* t. 39. f. 197. *Macrocheilus* (*Murex*) *harpula*, Sow. (M. C. t. 575. f. 5), has much affinity also with our shell; again, certain American *Loxonemæ* have *body*-whorls which cannot be distinguished from our specimen. Prof. Morris has suggested that our doubtful fossil may be a small Goniatite, with a wide umbilical cavity, and the ribs passing over the back, each rib bearing a tubercle round the umbilicus. I am still disposed to regard it as the body-whorl of a Gasteropod, or a shell with very depressed whorls hidden in the matrix.

Loc. Don River. *Form.* Carboniferous.

Murchisonia carinata, Ether. Pl. XVIII. fig. 5.

Shell elongated, of many whorls (four exposed), strongly keeled or carinated along the middle of each whorl; no ornamentation seen, being a cast only.

Gasteropods appear so rare in these rocks that we venture to figure this in hopes that more perfect examples may be found.

* These are seen only near the aperture.

Obs. Sandberger, Die Verst. Rhein. Schicht. Nassau, t. 24, figures two or three species of elongated *Pleurotomariæ* resembling our shell in form, viz. *P. bilineata*, Goldf., *P.* (*Murchisonia*) *angulata*, Phill., and *P. nerinæa*, Sandb.; but these shells possess a double line around the middle of the whorls. The original *Murchisonia angulata* is figured by Prof. Phillips in Pal. Foss. Dev. & Cornw. t. 39. no. 189; but we cannot refer our shell to it. I have sought every source, but without success, to find any shell agreeing with our Queensland form.

Loc. Don River. *Form.* Carboniferous.

Griffithides dubius, Ether. Pl. XVIII. fig. 7.

Body elongated, oval, length about twice the width, sides parallel. Axis width of pleuræ. Thoracic segments 10 to 12. Pygidium rounded, margins entire; axis composed of 10 segments, not extending quite to the posterior margin. Cephalic portion much crushed; glabella small and round anteriorly, furrows indistinct.

Owing to the crustaceous test being removed, we have no means of arriving at the condition of the original ornamentation; there are, however, indications of tubercles upon the axis of the pygidium.

Obs. It is difficult to say in the badly preserved condition of this specimen whether it belongs to the genus *Phillipsia* or to *Griffithides*, the mutilation of the head preventing our seeing important characters. I refer it, however, to *Griffithides*. This is the only Trilobite I have ever seen from any of the Palæozoic rocks of Australia younger than Silurian. It much resembles our British forms, especially those of the Carboniferous series; and as the associated fauna is undoubtedly of this age, we also assign *G. dubius* to the same horizon. This is very distinct from the other genera of the Proetidæ in the Silurian rocks; the moderate development of the cephalic shield, form of glabella, and more elongated body separate it from any known Silurian form.

Loc. Don River. *Form.* Carboniferous.

Mesozoic.

Cretaceous.

Cyprina expansa, Etheridge. Pl. XIX. fig. 1.

Shell ovato-quadrate, elongated; umbones prominent; umbonal region thick; ventral margin compressed; dorsal margin nearly straight; posterior side slightly truncated; the line determining the position of the anal adductor and the siphonal sinuses are nearly at right angles to the length of the shell; these and the pallial sinus are well marked.

Obs. This shell appears to have attained to considerable dimensions in the Australian Cretaceous seas, being much larger than the *Cyprina planata* of the Lower Tertiaries of Britain and France. In form and habit *C. expansa* is closely allied to *C. planata*, possessing also the compressed ventral border, deep lunule, and expanded anterior or pedi-lateral margin. Of the many examples we have of this species none possesses any shell-structure; they occur in the form of casts only, and appear to abound in the Cretaceous beds of Maryborough. Figure reduced $\frac{1}{2}$.

Loc. Maryborough. *Form.* Cretaceous; horizon doubtful.

TRIGONIA NASUTA, Etheridge. Pl. XIX. figs. 2, 2 *a*.

Shell triangular or deltoid, much produced or elongated at the posterior end; anterior side truncated; umbones prominent and thick; hinge-area and teeth not preserved, save a few on the posterior area.

Obs. We possess only the cast of this shell; and had it been found in the Cretaceous rocks of Britain we should have allied it to *Trigonia alæformis*, Park., or *T. caudata*, Ag.; our shell, however, from the umbo to the ventral margin, is much higher or deeper than either of the two forms referred to. We have no means of ascertaining the ornamentation upon the shell, or whether it was simply ribbed, or tuberculated. I am inclined to believe that the concentric folds or ribs supported tubercles upon them, as in *Trigonia scabra* and *T. caudata*. Only one specimen has occurred; but I unhesitatingly refer it to the Cretaceous deposits; it belongs to a type not known in the Jurassic rocks. *T. sanctæ-crucis*, Pictet and Camp., much resembles this shell. C. L. Griesbach, Esq., describes and figures a *Trigonia*, from the Umtamfuna river, Natal, which has an elongated posterior end and in general shape and deltoid form is much like our shell; want of external structure, however, prevents our making further comparison.

Loc. Maryborough. *Form.* Cretaceous; horizon doubtful.

CRENATULA (?) GIBBOSA, Etheridge. Pl. XIX. fig. 3.

Shell elongated, somewhat deltoid; hinge-line thick, straight, about one third the width of the shell; umbo acute, slightly curved, no impression of pallial line visible; anterior slope appears to have gaped for the passage of a byssus, as in *Mytilus* (*but, possessing only one valve, this may be doubtful*); ventral margin broadly rounded and flattened; lateral margin slightly expanded; umbonal region very deep. Although I have figured this cast, I am nevertheless at a loss to know where to place it; I however refer it to the subgenus *Crenatula*. The single muscular scar places it in the section Asiphonida Integripallialia; one specimen only, and that a cast of the right valve, occurs in the collection: our shell may have some affinity with *Pulvinites*; but at present the nature of the hinge-line and hinge-area is not known. I however suggest this.

Much interest is attached to this singular cast; and I trust our figure will enable Australian collectors to furnish us with more perfect specimens. I am disposed to regard it as a new genus; but the want of more evidence and better materials restricts me from further description. Figure reduced $\frac{1}{4}$.

Loc. Maryborough. *Form.* Cretaceous.

Genus? Pl. XIX. fig. 4.

Shell apparently smooth, semicircular, nearly equilateral, equivalve; umbones central, slightly acute and anterior; posterior and ventral margins equally rounded and smooth; hinge-line straight, rounded at the angles, giving the shell an almost circular appearance.

Obs. It is to be regretted that we have not a particle of the original shell wherewith to recognize the nature of the markings, or even the ventral margin to aid us in determining whether the inner edge was crenulated or plain; externally the shell appears to have been smooth or delicately concentrically marked. The cast of the hinge-line is such as to prevent our determining any teeth below the junction of the two valves.

In outward form this shell much resembles *Lucina* (*Codallia*) *percrassa*, Stol., from the Arrialoor Group (India); and the shell is nearly equal in length to that of this species, but not so high. The pallial line appears to be simple; and the muscular impressions resemble those of *Pectunculus*. Some *Axineæ* from the Indian Cretaceous rocks, but for their size, would very closely resemble this shell. We possess one specimen only, and that a cast of one valve. Figure reduced $\frac{1}{2}$.

Loc. Maryborough. *Form.* Cretaceous.

Cucullæa robusta, Ether. Pl. XX. fig. 1.

Shell trapeziform, rhomboidal, elongated, with valves ornamented with thirteen or fourteen thick costæ or ribs; hinge-area moderately wide, with four horizontal teeth; umbones much incurved. Unfortunately this form does not possess any shell, occurring as a cast only, but distinctly showing the place of the well-pronounced ribs and teeth.

Obs. In form *C. robusta* resembles *C. oblonga*, from the inferior Oolite, and casts of *C. Beaumontii*, D'Orb., from the lowest White Chalk or beds equivalent to our Chalk marl and Coprolite series; but the external shell must have been very different when living.

Loc. Maryborough. *Form.* Cretaceous.

Cucullæa costata, Ether. Pl. XX. fig. 2.

Shell deltoid in shape, nearly equilateral; umbones large and very distant; the ligamental area wide; hinge-line straight (teeth not seen in this specimen*); pallial line straight; anterior and posterior sides truncated (in the cast); ribs well defined on remaining portion of shell, perhaps eighteen to twenty in number, with transverse costæ between the ribs; the ventral margin appears to have been closed.

Obs. This species is abundantly represented in these rocks, but all in the form of casts; we are, however, enabled to figure a small portion of the shell which remains upon the specimen, and suffices to indicate that it possessed strong or well-defined ribs and slightly cancellated interspaces.

Loc. Maryborough. *Form.* Cretaceous.

* A specimen in the collection shows three horizontal hinge-teeth along the posterior edge of the left valve.

Nucula quadrata, Ether. Pl. XIX. fig. 5—Pl. XX. fig. 3.

Shell quadrate and tumid, umbones anterior, and anterior side short and vertical; posterior side much elongated and sharply rounded; teeth on posterior side large and numerous; those on anterior side few (seven or eight) and smaller; posterior dorsal margin flat.

Obs. Two specimens only occur in the collection; but neither this species nor *N. gigantea* shows the inner surface of the shell, and therefore no crenulations are seen along the ventral margin; the muscular scars and pallial sinus are well defined in the cast.

Loc. Maryborough. *Form.* Cretaceous.

Nucula gigantea, Ether. Pl. XX. fig. 4.

Shell ovately oblong; dorsal margin nearly horizontal; ventral margin nearly semicircular; umbones placed very anteriorly and nearly straight; hinge-teeth thirteen or fourteen, on posterior side, and five or six on anterior side of umbo. No external shell occurs on any of the *Nuculæ* in the collection.

Loc. Maryborough. *Form.* Cretaceous.

One specimen only in the collection.

Leda elongata, Ether. Pl. XX. fig. 5.

Shell elongated, length nearly double the height; umbones nearly central, nearer anterior than posterior margin; teeth very numerous on both sides of umbo—anterior twelve or thirteen, posterior fifteen.

Obs. This shell much resembles *Leda scapha*, D'Orb., "Étage aptien" of France and Gault of England, but is larger. Some *Yoldiæ* from the Arrialoor group of the Indian Cretaceous rocks outwardly resemble this species, especially *Y. scaphuloidea*, Stol. It is, however, quite distinct. Figure magnified twice.

Loc. Maryborough. *Form.* Cretaceous.

Tellina mariæburiensis, Ether. Pl. XX. figs. 6, 6 *a*.

Shell compressed, transversely elongated, nearly equilateral, acutely rounded anteriorly; posterior margin slightly truncated, lines of growth strongly marked and band-like; these concentric bands are broad and of equal width; shell-structure absent.

Obs. In many respects this shell resembles *Tellina* (*Palæomœra*) *inconspicua*, Forbes, from Trichinopoly; but the band-like markings, if in the external shell, which they appear to be, remove it from that species; in form, size, and habit, however, it closely approaches it.

Loc. Maryborough. *Form.* Cretaceous.

Tellina, sp. Pl. XX. fig. 7.

I figure this form of *Tellina* as being a common shell in the collection; it is less elongated and more deltoid in form than *T. mariæburiensis*, and apparently possessed a smooth shell instead of the banded structure of that species; the anterior side is obtusely rounded, and the posterior more acute. I figure this specimen, but venture not to give it a name until more perfect specimens occur.

Loc. Maryborough. *Form.* Cretaceous.

AVICULA ALATA, Ether. Pl. XX. fig. 8.

Shell inequivalve, inequilateral; auricles unequal, posterior much expanded, anterior small; hinge-line straight, umbones acute and prominent, umbonal region thick; valves with numerous (34) radiating ribs, with alternating smaller ones, except near the middle of the valve, where the ribs (7 and 8) are all equal, and range from the umbo to the ventral margin.

We have no means of ascertaining the character of the hinge-line or teeth, the ligamental area being concealed in the matrix; and the shell-texture is absent, or wanting.

Loc. Maryborough. *Form.* Cretaceous.

NATICA LINEATA, Ether. Pl. XXI. fig. 1.

Shell globose, spire depressed, consisting of three or four volutions, sutural line deep; aperture large and oval; body-whorl large, rapidly increasing in size, strongly rugose, or varied by lines of growth.

Obs. This shell closely resembles *N. gaultina*, from the Gault of Folkestone, also from the Greensand of Blackdown. It may be the *Natica variabilis*, Moore, figured as coming from the Wollumbilla beds, which it most resembles. I cannot, however, satisfy myself that it is the same shell, and, therefore until better specimens are obtained, retain the name.

Loc. Maryborough. *Form.* Cretaceous.

PANOPÆA SULCATA, Ether. Pl. XXI. figs. 2, 2 *a*.

Shell oblong, transversely or ovately elongated, thin, with many, concentric, deeply sulcated plications or furrows; umbones pointed, anterior side much rounded, posterior side acute.

Obs. This shell resembles *P. orientalis*, Forbes*; but the concentric sulcations are fewer and coarser, the posterior margin is more acute, and the umbones slightly more central. It also much resembles *P. Prevosti*, D'Orb.; but our shell is more coarsely plicated than either of the above-named species.

Loc. Maryborough. *Form.* Cretaceous.

PANOPÆA (MYA) PLICATA, Sow., var. ACUTA, Ether. Pl. XXI. figs. 3, 3 *a*.

Ref. Min. Conch. vol. v. p. 20, pl. 419. f. 3.

A variety of this common and well-known European shell is evidently abundant at Pelican creek, and is, with one other exception, the only British Cretaceous species we have met with in the Queensland collection. *P. sulcata*, mihi, from Maryborough, differs much from this shell, although individuals of both sexes are frequently crushed and distorted. To what particular horizon in the Cretaceous series to refer this variety of *P. plicata* I cannot

* From Pondicherry (Trans. Geol. Soc. ser. 2, vol. vii. pl. 17. fig. 4).

pretend to define; and only a few other fossils occur or are associated with it in the collection.

In Europe and Britain the type form is abundant in the Neocomian, Gault, and Upper Greensand beds.

Our shell is more acute than Sowerby's typical form, the posterior or anal border or extremity in this variety being less truncated; it however gapes as much. I do not believe it is more than a varietal form.

Loc. Pelican Creek. *Form.* Cretaceous.

Inoceramus marathonensis, Ether. Pl. XXII. fig. 1.

Shell elongated and compressed; umbonal region narrow, acute, and tapering; ventral portion of shell much expanded (much of specimen lost); concentric plications or undulations variable, being alternately broad and narrow, and unequal.

Obs. We possess only one specimen of this form; and that includes only about two thirds of the original shell, the ventral margin being lost. In size and shape it somewhat resembles *I. annulatus* from the White Chalk of Westphalia; but the want of the true outer shell prevents our referring it to that species, the equidistant lines of growth in *I. annulatus* being characteristic and well defined.

Prof. M'Coy (Trans. Royal Soc. Victoria, vol. vii. 1866, p. 57) describes a shell from the Flinders range, which he calls *I. Sutherlandi*, referring to it as having affinity with *I. Cuvieri* through its concentric undulations, shape, and size, but having a more acute or narrow anterior end; want of a figure throws doubt upon the identity of our two shells.

Inoceramus multiplicatus, Stol., var. elongatus, Ether. Pl. XXII. fig. 2.

Ref. Pal. Indica, vol. ii. t. 28. f. 1, p. 406.

Shell much elongated, with numerous concentric ribs, which become coarser and flatter near the ventral margin; umbones acute and apparently incurved; whether they approximate or not we have no means of determining, as we possess only one valve.

With the exception of being more elongated than the shell described by Dr. F. Stoliczka, Pal. Indica, vol. iii. p. 406, t. 28. f. 1, our shell appears to be the same species, allowing for those variations which the species in this genus exhibit. It is not so ventricose a shell as *I. striatus*, Mant., from the Lower Chalk of Sussex, Saxony, &c.

At first I was inclined to refer this shell to *I. problematicus*, D'Orb., of the "Etage Turonien," or lower white Chalk of France; but the peculiarity of the concentric folds removes it from that species.

Loc. Marathon station, Flinders River. *Form.* Cretaceous.

Inoceramus pernoides, Ether. Pl. XXII. fig. 3.

Shell quadrate, deep; umbonal region thick and elevated; beaks acute; anterior side slightly convex; the ventral margin broadly rounded; surface marked by alternating groups of fine and coarse concentric folds, or large undulations.

Obs. This shell much resembles *I. regularis,* D'Orb., in shape, size, and markings; but the wing or hinge-area is not so long. It is also almost identical in shape with *I. Lamarckii, I. latus,* and *I. crispus,* Mant.; but the concentric undulations are not so unequal and pronounced, neither had this shell a corrugated and thickened fold along the hinge-line as in *I. Lamarckii*; the teeth or hinge-pits are not seen. It is evident that this was an abundant species in the Cretaceous seas of Queensland, its remains being numerous and usually fragmentary.

Loc. Marathon station. *Form.* Cretaceous.

INOCERAMUS allied to *I. problematicus*, D'Orb. Pl. XXII. fig. 4.
Ref. Pal. Franç. vol. iii. p. 510, pl. 406.

I cannot see characters sufficiently good to distinguish specifically this form of *Inoceramus*; and we have only one specimen. D'Orbigny's figures are variable enough to allow of any latitude in this species; and his figures 5 and 6 show characters occurring in our shell. *I. mytiloides,* Sow., may be referred to as having considerable resemblance; a large number of specimens, however, should be examined before the species can be determined, where so much variation and similarity exists.

Prof. M'Coy (*loc. cit.* p. 50) has described an *Inoceramus* as *I. Carsoni,* and states that it exactly resembles *I. mytiloides,* Sow., but has a longer hinge-line, more pointed anterior end, and more obtuse superior posterior angle than Sowerby's species. I had, prior to seeing Prof. M'Coy's notice, referred this shell to *I. mytiloides,* Sow.; but it has more affinity with *I. problematicus,* D'Orb.

Loc. Marathon station. *Form.* Cretaceous.

CRIOCERAS or ANCYLOCERAS.

There is not enough of this specimen to warrant its being figured; and what may have been the character of the outer shell has to be determined. It is evident the species was large; but whether to be referred to *Ancyloceras* or *Crioceras* is even doubtful.

Mr. Moore, Quart. Journ. Geol. Soc. vol. xxvi. p. 257, t. 15. f. 3, has described and figured a species of *Crioceras* from the Upper Maranoa district (E. Australia), which much resembles our specimen; his species, however, had an inner whorl, which determined the genus to be *Crioceras*, through the non-involute condition of the coils. It is difficult, if not impossible, to determine whether the Queensland fossil is an *Ammonites*, *Crioceras*, or *Ancyloceras*. My reason for venturing to believe it to be *Crioceras* arises from the completeness of the ventral surface of the whorl and what would appear to have been a space between the first and second coil or whorl, now filled by the matrix in which the shell is imbedded. Our shell must have been of considerable size, measuring little less than 12 or 14 inches in diameter, and the ribs faintly bifurcate from the centre of the whorl, but without any tubercle at the point of bifurcation.

Ammonites Sutherlandi, Ether. Pl. XXI. fig. 4.

Shell discoidal; whorls three or four, with flattened sides, and six or seven transverse wavy furrows on the outer whorl; these are slightly inflected forwards on the sides of the shell, and pass over the back at right angles to the keel; back sharply convex; the surface of the shell appears to have been marked by, or ornamented with, fine lines or striæ apparently arranged at a different angle from the sulci or furrows.

Umbilicus small, well exposed, its walls rounded; aperture oval, elongated, or acutely ovate.

Obs. A very small portion only of the shell remains upon the side of the outer whorl, between the last two sulci, and shows faintly the fine undulating lines. The sutures are so indistinctly marked that I cannot refer them to any known species.

A. Sutherlandi has affinity with *A. cassida*, Raspail, from the Neocomian (Lycée, p. 115, no. 2; Ann. des Sc. d'Observation, t. iii. pl. 11. f. 3); but the sulci or furrows are fewer and wider, and the umbilicus smaller. None of the group Ligati, in the fine Indian collection named and described by Ferd. Stoliczka (Mem. Geol. Surv. of India) affords any clue to the form from Queensland, although some twenty-eight Indian species belong to this group. The smallness of the umbilical cavity and depth of the outer whorl remove this form from any species with which we can ally or compare it.

I name this species after one of the earnest explorers of Queensland.

Ammonites Beudanti, Brongn., var. Mitchelli, Ether. Pl. XXIII.

Shell discoidal, compressed, composed of four or five volutions or whorls rapidly increasing; sides nearly flat, ornamented with gently elevated undulating or sigmoidal ribs or folds bending towards the aperture, and about half an inch apart on the middle of the whorl. These and the interspaces are occupied by delicately arranged equidistant parallel lines or costæ, which pass over the back; aperture oval, back rounded and narrow, no keel; inner whorls exposed; walls of umbilical cavity angular, flat-sided, or bevelled and smooth.

Obs. This Ammonite, in its intermittent folds, involution of whorls, and general habit much resembles *A. Beudanti*, D'Orb., from the Gault of England and France, to which it is certainly closely allied.

Since writing the above I have seen Prof. M'Coy's description of *A. Flindersi.* It agrees so closely with my own that I believe them to be the same species. No figure accompanies M'Coy's description, which is to be regretted. Should, however, our shell be the *A. Flindersi* of M'Coy, the above name must be abandoned, unless M'Coy's form is really the *A. Beudanti*, D'Orb. I name the varietal form after J. L. Mitchell, Esq., whose early labours, researches, and travels in Australia deserve the highest consideration. Figure reduced $\frac{1}{4}$.

Loc. Hughenden. *Form.* Lower Cretaceous.

Ammonites Daintreei, Etheridge. Pl. XXIV.

Shell discoidal; whorls depressed or flattened at the sides, with a rather narrow rounded back. The sides of the shell ornamented with numerous nearly equal and closely arranged ribs, all of which are slightly arcuated and pass over the back or dorsal edge; umbilicus wide and deep, allowing half the inner whorls to be exposed; sides of the whorls around the umbilicus steep-sided, rounded, or subangular; aperture broadly oval, the outer whorl embracing two thirds of the next inner whorl. The ribs at the terminal portion of the last or body-chamber are somewhat unequal and coarser.

Obs. I have searched every available source for information relative to this shell, and cannot recognize any species approaching it in the Cretaceous rocks of Europe, India, or America. It has some affinity with *A. asterianus*, D'Orb., but wants the tubercle around the umbilicus; and the ribs are greatly bent or slightly sigmoidal, whereas in *A. asterianus* they are straight. It also resembles some forms or varieties of *A. Herveyi* in the ribs, but is not so tumid a shell. It occurs associated with *A. Beudanti*, D'Orb., *Ancyloceras*, and *Inocerami* in the Hughenden beds, which certainly appear to be Lower Cretaceous, or not younger than the Gault; the scantiness of the known fauna, however, does not allow us to assign the fossil remains to a definite horizon, such as Neocomian or Gault. Figure reduced $\frac{1}{4}$.

Loc. Hughenden. *Form.* Lower Cretaceous.

Avicula hughendenensis, Ether. Pl. XXV. fig. 3.

Shell oblique; umbones incurved; ears unequal; posterior ear long, anterior short; cardinal line straight; ventral margin broadly convex or rounded; surface of shell exhibiting a large number of slightly wavy or undulating vertical ribs or costæ, and many concentric undulating wavy folds, partly due to lines of growth; anterior side slightly concave near the ear, afterwards becoming curved and convex continuously with the base; surface highly polished in all the specimens.

Obs. This shell appears to have been very abundant and, *perhaps*, gregarious, masses of them occurring together, forming a compact and dense argillaceous limestone. I cannot refer it to any known species.

Loc. Hughenden station. *Form.* Cretaceous.

Aspidorhynchus, sp.?

The caudal portion of the vertebral column, tail, and several of the peculiar elongated scales of this genus occur in the Hughenden collection.

Oolitic.

Belemnites.

From Belcombe Creek, Black Downs, have been derived two, if not three, species of Belemnites, all of them much broken. The phragmocones in some cases are well preserved, and also the alveolar cavities, with portions of the guard. These fragments enable me to place them in the Middle or Upper Oolitic series. I can hardly detect any difference between the Queensland specimen and our *B. abbreviatus* from the Oxford Clay and Coral Rag, &c. There is another specimen with a more slender phragmocone; but the nature and size of the guard cannot be ascertained. We also possess numerous broken fragments and longitudinal halves of Belemnites which cannot be really determined.

Pleurotomaria Cliftoni, Etheridge. Pl. XXV. fig. 4.

Shell trochiform, spire elevated, apex acute, whorls 4–5, rapidly increasing. Body-whorl large. Aperture large, and nearly round, base convex. Columella thick, umbilicus apparently wanting or very small.

Obs. The body-whorl is more than double the dimensions of the preceding or fourth whorl, and proportionally much more globose, and crossed diagonally by delicate lines of growth at an angle of 45°. The rather broad sinus occupies the upper half of the body-whorl. I find great difficulty in referring this shell specifically to any known British form. It, however, resembles *Turbo* (*Pleurotomaria*) *Dunkeri*, Goldf. from the Middle Lias.

We have only two specimens, which are associated with *Myacites*, *Homomya*, and *Pholadomya* from the Oolitic deposits of Gordon Downs.

I name this specimen after Mr. Clifton, who has thrown much light upon the Mesozoic fossils of Australia.

Loc. Gordon Downs. *Form.* Oolite.

Homomya, Ag. Pl. XXV. fig. 5.

We appear to possess two specimens of this subgenus of *Pholadomya*. The absence of radiating costæ, and the somewhat wrinkled surface of the shell, as well as the position of the umbo and the gently curved hinge-line, favour the view that the two casts belong to the genus *Homomya*; neither to *Myacites* nor to *Pholadomya* can they be referred. I therefore place them with the above genus, and wait the opportunity of examining better specimens.

These and the following specimens from Gordon Downs all occur in a micaceous, sandy or arenaceo-calcareous Limestone. The matrix resembles the Yorkshire deposits, and, like many of the organic remains in that area, they possess no outer shell whatever; fragments of wood occur also.

Loc. Gordon Downs. *Form.* Lower Oolite.

Pholadomya. Pl. XXV. fig. 6.

Sufficient indications of the ribs remain on this single valve to determine this cast to belong to the genus *Pholadomya*. The hinge-line also and place of the hinge-area help us to assign this to the genus named; the impressions of some eight or ten ribs are distinguishable from the umbo to near the ventral margin of the shell. I was in doubt as to whether the slightly intermittent lines might not have represented the granulated surface or pitted structure of some *Myacites*; I however refer it to the above genus.

Loc. Gordon Downs. *Form.* Lower Oolite.

MYACITES, sp.? Pl. XXV. fig. 7.

This widely distributed genus occurs in grey and red sandy limestone at Gordon Downs; but I cannot specifically name either of the specimens in the collection: they are merely casts, and may be referred to many such occurring in the Lower Oolitic rocks of Britain; they are associated with other forms occurring in the Inferior Oolite of Europe. Externally the casts resemble those of *Myacites tenuistriatus* and *M. recurvus*; and a portion of the shelly structure remaining appears to be the same. It is essential that these forms should be mentioned and figured, owing to their position; and they are undoubtedly of the age assigned to them, whatever relation the deposits may have to those of Europe in time.

Loc. Gordon Downs. *Form.* Lower Oolite.

MYACITES allied to *M. tenuistriatus.*

In the absence of all other evidence I refer this cast to the above species; in all essential particulars it is that to which we refer those forms in our own Oolitic rocks that have been denuded of their shell, and which, by close comparison, agree with the known determined species.

Loc. Gordon Downs. *Form.* Lower Oolite.

TANCREDIA, sp.? Pl. XXV. fig. 8.

The subequilateral, transverse, and donaciform shape of this cast can only, I think, be referred to the genus *Tancredia*, Lycett (*Hettangia*, Terquem). No teeth, true hinge-line, or entire pointed anterior extremity are seen; but the aspect of the shell favours this belief. It, however, resembles *some forms* of *Corbis*. It may be referred to *C.* (*Corbiella*) *bathonica*, Lycett. Like the other casts from the Lower Oolite they are named to draw the attention of Queensland geologists to the Gordon-Downs fossils.

Loc. Gordon Downs. *Form.* Lower Oolite.

Note.—Since my Appendix has been in type I have examined another large series of fossils from Queensland, forwarded by Mr. William Hann. Nearly the whole are Cretaceous, and agree in facies with the Marathon and Hughenden series just described. The localities from which they are derived are Bowen Downs, head of Thompson River, Tower Hill, and Barcoo-River beds near Tambo.

The fossils from Bowen Downs occur in lat. 23° S. and long. 145° E.

They evidently belong to the same series, or are upon the same horizon, with the Marathon beds described in Mr. Daintree's paper. The specimens from Thompson River greatly resemble those species occurring in the Hughenden beds. The Tower-Hill fossils, from lat. 22° S., long. 144½° E., appear to be reassorted, and may have been laid down under freshwater or estuarine conditions. Vast numbers of Belemnites, with siliceous pebbles in a calcareous matrix, all rolled together, make up the chief mass of this rock.

The Barcoo-River beds (lat. 24° 50′, long. 146° 25′) near Tambo are certainly of the same date as the Marathon Ammonites of the Group Ligati (*Am. Sutherlandi*). North of Barcoo River (lat. 22° 40′, long. 144° 50′), we possess specimens from a well 100 feet deep; these bear the appearance of Gault forms, and resemble the normal condition of that deposit in England and France. Ward-River group, head of Warragoo, are conglomerates of doubtful age. Again, at the Barcoo river, fifty miles below the junction with the Alice river, *Inocerami* occur, which appear to me to be Gault.

These interesting fossils will receive further elucidation; it was, however, deemed of sufficient interest to thus notice their occurrence, which bears out geographically the distribution of the Cretaceous series previously noticed in the body of the Appendix, and confirms the view taken of the great westerly extension of the Cretaceous rocks through the plains of Queensland, thus perhaps accounting for the universally and widely spread level land in the western plains.

List of Fossils from Queensland.

Devonian Fossils.

Gympie.

Aviculopecten limæformis.
—— imbricatus.
—— multiradiatus.
Edmondia concentrica.
—— obovata.
Productus cora.
Spirifera bisulcata, *var.* acuta.
—— vespertilio.
Spirifera dubia.
—— undifera, *var.* undulata.
Strophomena rhomboidalis, *var.* analoga.
Pleurotomaria carinata.
Euomphalus —— ?
Fenestella fossula.
Ceriopora ? laxa.

Carboniferous Fossils.

Bowen River.

Streptorhynchus Davidsoni.
Productus Clarkei.
Spirifera striata.
Spirifera convoluta.
—— *allied to* bisulcata.

Head of Don River.

Strophomena rhomboidalis, *var.* analoga.
Productus longispinus.
Spirifera *allied to* striata.
Natica (Naticopsis ?) harpæformis.
Murchisonia carinata.
Griffithides dubius.

Wealwandanga.

Productus *or* Strophalosia.

Cracow Creek.

Chonetes cracowensis.

Pleurotomaria rotunda.

Cretaceous Fossils.

Maryborough.

Cyprina expansa.
Trigonia nasuta.
Crenatula ? gibbosa.
——? ——?
Cucullæa robusta.
—— costata.
—— quadrata.

Nucula gigantea.
Leda elongata.
Tellina mariæburiensis.
——, sp. ?
Avicula alata.
Natica lineata.
Panopæa sulcata.

Marathon Station.

Inoceramus marathonensis.
—— multiplicatus.
—— pernoides.

Inoceramus *allied to* problematicus.
Ancyloceras, sp.

Hughenden.

Avicula hughendenensis.
Ammonites Beudanti, *var.* Mitchelli.

Ammonites Daintreei.
Aspidorhynchus (tail and scales).

McKinlay Range.

Ammonites Sutherlandi.

Oolitic Fossils.

Pleurotomaria Cliftoni.
Homomya.
Pholadomya.

Myacites, sp.
—— *allied to* tenuistriatus.
Tancredia.

Appendix II.

Notes on Fossil Plants from Queensland, Australia. By WILLIAM CARRUTHERS, Esq., F.R.S., F.G.S., Keeper of the Botanical Department in the British Museum.

THE fine series of Lepidodendroid remains from the Old Red Sandstone rocks are perhaps the most important group of fossil plants which Mr. Daintree has brought from Queensland. They supply the means of restoring a remarkable plant in all its parts, fragments only of which have been hitherto known, and these have been misunderstood and misinterpreted. Further, they clear up the reports that have at times been circulated as to the occurrence of a *Lepidodendron* in the Australian coal-beds, which Mr. Keene affirmed he had seen, and on which the Rev. W. B. Clarke depended to some extent to establish the palæozoic age of the coal. It is true that the investigations of Prof. M'Coy established that Mr. Clarke's *Lepidodendron* did not belong to the Coal-beds; but we are now, at least in this country, supplied for the first time with the materials for clearing up the history and adding something to our knowledge of this plant.

Unger was the first to describe this plant, in his memoir on the flora of the Upper Devonian beds of Thuringia (Denkschr. Akad. Wissen. Wien, vol. xi. (1856) p. 175, tab. x. f. 4–8). He figures the terminal fragment of a branch, four inches long and half an inch broad at its lower end. The piece is thick and blunt at the apex, and is covered with spirally arranged somewhat obsolete cicatrices of the leaves. The outer surface of the branch is shown only on the lower third of the specimen; and there the leaf-scars are seen to be contiguous and rhombic. The specimen was so well preserved as to exhibit the internal structure, which is figured, and agrees, as Unger says, very closely with that of *Lepidodendron Harcourtii*, Witham.

In 1860 Prof. Dawson published his first account of the Devonian plants of Canada; and he figured some fragments to which he gave the name of *Lepidodendron gaspianum* (Quart. Journ. Geol. Soc. vol. xv. p. 483, fig. 3). One of the figures shows the surface to be marked with rhombic leaf-scars; and these are still more manifest in the illustrations to a subsequent memoir (Quart. Journ. vol. xviii. (1862) pl. xvii. f. 58), and in his Acadian Geology (p. 542, fig. 189 A). These show besides the impression of the vascular bundle in the centre of the rhombic scar.

For another fragment of what I believe to be the same plant, Prof. Dawson in the memoir just referred to (*l. c.* vol. xviii. p. 316) proposed a new genus, *Leptophlœum*, characterized by the stems having thin bark and a very large pith-cylinder with transverse markings of the character of *Sternbergia*. A specimen is figured (*l. c.* pl. xvii. fig. 53), which shows, according to the author, "a growth of young wood at the extremity of the stem, on which the rhombic scars are only imperfectly developed; and at the extremity of this younger portion the transverse structure of the pith exhibits itself through the thin bark in such a manner that this portion, if separated from the remainder of the stem, might be described as a *Sternbergia*."

In the following year Prof. Dawson described what he believed to be the foliage and fruit of this plant, in a further contribution to the Canadian Devonian plants (*l. c.* vol. xix. (1863) p. 462), and he gives in plate xviii. fig. 19 a restoration of the plant exhibiting these additions. As, however, he omits all notice of these parts in his recent memoir on Pre-Carboniferous floras (1871), it may be supposed that he is not satisfied as to this correlation of the different parts.

This historical account supplies also a statement of what is known regarding this plant.

The large series of specimens belonging to Mr. Daintree, as well as those already in the Museum of the Geological Society, are all merely casts, generally in a finely grained rock, which must have been deposited as a very fine mud, as it has insinuated itself between the leaves, filling up every crevice, and preserving the parts, allowing for the compression they have received in the compacting of the beds, in their natural relations. Sometimes the interior of the stem is filled with the amorphous material of the rock, and exhibits on both its surfaces the leaf-scars as in fig. 9 of Plate XXVI. and in several large trunks.

Lepidodendron nothum, Ung., had for its roots a *Stigmaria* which cannot be separated from *S. ficoides*. The actual connexion of the stem with the roots is not shown in any of the specimens; but that this is their relation cannot be doubted, as these are almost the only fossils found in the beds, and certainly the only ones that could be thus related.

The leaf-scars vary considerably in size in different parts of the stem, and when not affected by pressure are rhombic in form. The largest scars are shown in fig. 12 (Pl. XXVI.); and these are without any scar from the vascular bundle. This scar is generally present, but it does not always occupy the same position in the larger leaf-scar; sometimes it is in the centre, as in fig. 10; sometimes at the apex, as in figs. 8 and 11; and in others it gives a longitudinal impression extending from nearly the bottom to the top of the scar (fig. 9). This is as might have been expected, seeing that the small scar is produced by a portion of the tissue which was more persistent than the parenchyma that surrounded it, and which was able to offer some resistance to the soft mud that filled the decayed cavity of the stem. The direction of this vascular bundle was upwards and outwards from the vascular cylinders, as in other Lepidodendrons, and as is shown in Unger's specimens. Freed from the surrounding cellular tissue, but yet attached to the vascular cylinder at the one end and to the indurated cicatrix at the other, it might retain its position in the centre of the scar, or be carried to one or the other end of it by the pressure of the invading mud, according to the direction in which the mud came, or might even be pressed against the cicatrix throughout a considerable portion of its length. It is thus obvious that the position of the scar and the presence of a furrow introduced by Dr. Dawson into his diagnosis of the genus and species are of no value.

The form of the leaf-scar is also liable to considerable variation from pressure. Two such forms are given in figs. 13 and 14.

The increase in the size of the scars in proportion to the dimensions of the stems on which they are borne, may be traced in the figures 7, 8, 9, 10, 11 and 12. In the first three of these figures the scars are suddenly flattened, and pass into subtriangular and ultimately into narrow linear scars. This condition Dr. Dawson considers due to the large *Sternbergia*-pith showing through the thin bark; but it is really owing to the incomplete development of the bases of the leaves. There has been an interruption to the growth where the rhombic scars stop. Below this line I have not been able to detect the trace of leaves in the matrix; but above in the growing apices of the branches the leaves are abundant (fig. 1). The leaves are very small and peltate, with roundish petioles as long as the leaf itself. The petiole was placed at right angles to the stem, and was attached to the lamina of the leaf about one third up from its lower edge. The larger upper portion of the leaf overlapped the lower portion of that above it, so that externally the branch was completely hidden by the covering of peltate, imbricate, and pedicellate leaves. In the slender and dichotomously divided branch (fig. 7), the leaves seem to have been ordinary leaves; but in the thicker and simple branch represented at fig. 1, a slight protuberance, which can be detected on the middle of several of the petioles, indicates, as it seems to me, that these were fruit-bearing. The resemblance these leaves bear to the fruit-bearing leaves of modern Lycopods is apparent from a comparison of fig. 5, representing *Lycopodium Gayanum*, Brongn., with the fossil, fig. 6.

The identity of this plant with Dr. Dawson's *Leptophlœum rhombicum* cannot be doubted; and the propriety of giving up the long, parallel-sided, and one-nerved leaves, and the strobiles borne on the sides of the branches, as I suppose he has done*, is thus fully justified.

Several specimens of the *Knorria*-condition of preservation of this plant are to be found in Mr. Daintree's collections. Inasmuch as the internal constitution of the stems of many of the more frequent Lycopodiaceous stems of palæozoic rocks was similar, it is impossible to discover in the accidental appearance of their internal and amorphous casts any characters which would justify our establishing them as species, or would enable us to refer them to a known species, in the interior of which they may have been formed. It is only in cases like the present, where but one species is found with the *Knorria*-casts to which they can belong, that certainty can be attained.

I may close this account by a more exact specific diagnosis supplied by the materials which I have now described.

LEPIDODENDRON NOTHUM, Unger (non Salter), Denkschr. Akad. Wissen. Wien, math.-natur. Cl. vol. xi. (1856) p. 175, pl. x. f. 4–8.

Scars of the leaves contiguous, rhombic, with a single and generally central vascular scar; leaves small, peltate and imbricate, on long slender petioles; fruit produced on the apices of the thick branches, a single sporangium, almost sessile, borne on the middle of the petiole of the leaf; roots stigmarioid.

The geographical distribution of this plant is remarkable. Dr. Dawson's figure leaves no doubt as to the identity of the Canadian and Australian plants, as far as the small fragments found in Canada enable one to come to a positive decision; and the same may be said of Unger's specimen from Germany. But this only confirms

* Compare Dawson in Quart. Journ. Geol. Soc. (1863) vol. xix. p. 462, with his 'Pre-Carboniferous Floras' (1871).

what has already been remarked in regard to the wide range of the Palæozoic plants.

I have previously recorded a species of *Lepidodendron* from South Africa, which cannot be separated from a common British species, and a species of *Flemingites* from South Brazil, closely allied to that of our own Coal-measures.

There is a small group of *Lepidodendra* in the Coal-measures, which by the form of their scars are closely related to this Devonian species. Indeed there are no characters in the portions yet known of them which justify their separation specifically from the Devonian plant. It cannot be doubted, however, that this is the result of our imperfect knowledge of these plants. The group I refer to is that for which Presl proposed the generic name *Bergeria* (Sternberg, Flora Vorw. vol. ii. p. 184); and if a new generic name is required to separate them from *Lepidodendron* proper, this, of course, must be adopted. We may add to the forms enumerated by Presl as belonging to this group the two following fossils:—*Lepidophloios tetragonus*, Dawson, and *Lepidodendron tetragonum*, Geinitz (non Sternb.).

Among the Devonian fossils presented by the Rev. W. B. Clarke to the Society's Museum, there is a fragment of a Lepidodendroid plant which I cannot separate from that found at Kiltorkan, to which Dr. Haughton gave the name of *Sigillaria dichotoma*, and afterwards of *Cyclostigma kiltorkense*, and which, after receiving many other *aliases*, should be named, I believe, *Syringodendron dichotomum*, it being a species of that genus as amended by Brongniart in his 'Histoire,' and again in his 'Tableau.'

A small fragment in Mr. Daintree's collection seems to indicate a third species of *Lepidodendron*, allied to if not identical with *Sagenaria obovata*, Eichwald. I cannot, however, be certain, from the single specimen, whether the markings are on the surface of the stem, and so sufficient to warrant its specific determination.

Portions of the rachis of a fern like those to which Baily has given the name of *Filicites lineatus*, and fragments of a *Calamites* (it may be *C. radiatus*, Brongn.), complete the list of Mr. Daintree's Devonian plants.

The remaining fossil plants Mr. Daintree refers to two horizons, the older characterized by the presence of *Glossopteris Browniana*, Brongn., and the younger by *Tæniopteris Daintreei*, M'Coy.

Glossopteris Browniana has been so frequently described and figured, that I find nothing additional worth recording from an examination of Mr. Daintree's specimens, unless it be that one shows some indications of fruit in the form of linear sori running along the veins, and occupying a position somewhat nearer to the margin of the frond than to the midrib.

In addition to the species which I have described and figured, there are associated with *Glossopteris* fragments of a small species of *Schizopteris*, apparently bearing fruit on the apex of the truncate segments; but the only specimen is too imperfect to justify giving it a specific name. The same may be said of a small but well-marked frament of *Pecopteris*, consisting of portions of two pinnæ allied to *P. australis*, Morris, but certainly different, as well as of a *Cyclopteris* in Keene's collections in the Geological Society's Museum.

In Mr. Daintree's upper horizon we find the following plants:—

Tæniopteris Daintreei, M'Coy. Plate XXVII. fig. 6.

Frond simple (?), broad, linear; midrib somewhat thick; veins leaving it at an acute angle, then passing out at right angles to the margin, once or twice dichotomously divided.

Loc. Tivoli Coal-mine.

Cyclopteris cuneata, sp. nov. Pl. XXVII. fig. 5.

Form of the entire frond unknown; pinnæ entire, large, cuneate, narrowed at the base, with the distal margins rounded; veins delicate, once or twice dichotomously divided; sometimes anastomosing once in their length near the middle of the pinna.

Notwithstanding the slight anastomosis of the veins, these separate pinnæ, which are not very frequent, represent a very distinct species of the genus *Cyclopteris*.

Loc. Tivoli Coal-mine.

Sphenopteris elongata, sp. nov. Pl. XXVII. fig. 1.

Frond dichotomously divided, each division irregularly pinnate; pinnæ simple, bifurcate, or irregularly pinnate; segments narrow, linear, slightly tapering upwards to the somewhat blunt apex; the single midrib sending out simple branches, which run along the middle of each segment.

With *Pecopteris odontopteroides*, Morris, this is one of the most abundant forms. Some specimens have small oval markings scattered irregularly on either side of the midrib. These probably indicate the form and position of the sori, which are the same as in some of the simple linear species of *Polypodium*.

Loc. Tivoli Coal-mine.

Pecopteris odontopteroides, Morris, in Strzelecki's 'New South Wales,' p. 249, pl. vi. figs. 2–4. Pl. XXVII. figs. 2 and 3.

Frond, with a very short and thick stipes, dichotomously divided, the simple portion at the base of the frond as well as each branch pinnatifid; the segments more or less opposite, quadrate-ovate, with the apex obliquely truncate, connate at the base; one vein passing into the centre of the segment and repeatedly dichotomous, several lateral veins, simple or dichotomous, passing direct from the rachis into the upper and under portions of the segment.

In the form of the segment our plant differs considerably from the specimens figured and described by Prof. Morris. It nevertheless belongs, I believe, to the same species. I am able to describe and figure the venation, which is well marked in several of the specimens. The dichotomous division of the frond is not sufficient to justify Prof. M'Coy's transference of this form to *Gleichenites*, with which in other respects it has no affinity whatever.

Loc. Tivoli Coal-mine.

CARDIOCARPUM AUSTRALE, sp. nov. Pl. XXVII. fig. 4.

Fruit cordate, with an acute apex, and a ridge running along one side of the fruit within and parallel to the edge; seed ovate, acute.

Loc. Tivoli Coal-mine.

With these are fragments of several plants, but too imperfect to permit their description as new species, or their reference with certainty to known species. Amongst them may be noted a narrow linea Træniopteroid frond, with ascending dichotomous veins, like *Pecopteris* (?) *salicifolia* from India, a *Tæniopteris* with simple veins passing out at right angles from the midrib, a before notified *Pecopteris* allied to *P. indica*, and a *Sphenopteris* with linear segments to the pinnæ.

These plants do not supply any additional data to those already known for determining the age of the beds in which they occur, and consequently of the coal associated with them. My investigation of the forms induces me to consider both series of nearly the same age, and to agree with Morris, M'Coy, Bunbuy, and Zigno in the opinion that they belong to the Oolitic period.

EXPLANATION OF PLATES IX.—XXVII.

PLATE IX.

Sketch Map of the Geology of Queensland.

PLATE X.

Fig. 1. Section showing structure of Diorite from Boyne Diggings, Calliope District, Queensland, enlarged 4 times.

2. Section showing structure of Diorite from Gympie Diggings, Queensland, enlarged 4 times. Analysis given, p. 293.

3. Section showing structure of Diorite from Granite Creek, Gilbert District, Queensland, enlarged 4 times. Analysis given, p. 303.

*** The general composition of these Diorites consists of triclinic felspar, hornblende, pyrites, and a little chlorite or epidote. It will be noted that the felspar crystals are larger, and the general structure coarser in these intrusive diorites and diabases than in the intrusive Dolerites of Pl. XII.

PLATE XI.

Fig. 1. Section showing structure of the Gladstone Trachyte, enlarged 4 times. Analysis given p. 312.

2. Section showing structure of Porphyrite, enlarged 6 times. Analysis given p. 303.

3. Section showing structure of Quartz-porphyrite from the Berserker Range, near Rockhampton, Queensland, enlarged 4 times. See p. 303.

PLATE XII.

Fig. 1. Section showing structure of intrusive Dolerite from Rockhampton Quarry, Queensland.

2. Section showing structure of intrusive Dolerite from the Black Mountain, Cape District, Queensland.

3. Section showing structure of Dolerite from the Clarke river, referred to in Mr. Allport's description, p. 313.

*** All these enlarged 4 times.

PLATE XIII.

Fig. 1. *Aviculopecten multiradiata*, Eth.
2. *Edmondia concentrica*, Eth.
3. —— *obovata*, Eth.

PLATE XIV.

Fig. 1. *Aviculopecten limæformis*, Morris.
2. *Aviculopecten ? imbricatus*, Eth.

PLATE XV.

Figs. 1 & 2. *Productus cora*, D'Orb.
3 & 5. *Strophomena rhomboidalis*, var. *analoga*.
4. *Spirifera undifera*, var. *undulata*, Röm.
6. *Pleurotomaria carinata*, Sow.

PLATE XVI.

Fig. 1. *Spirifera bisulcata*, Sow.
2. —— *vespertilio*, Sow.
3–5. —— *undifera*, var. *undulata*.
6. —— *dubia*, Eth.
7. *Strophomena rhomboidalis*, var.

PLATE XVII.

Fig. 1. *Streptorhynchus Davidsoni*, Eth.
2. *Productus Clarkii*, Eth.
3. *Spirifera convoluta* ?, Phill.
4. —— allied to *Sp. bisulcata*, Sow.
5. —— *striata*, Mart.

PLATE XVIII.

Fig. 1. *Strophomena rhomboidalis*, var. *analoga*.
2. *Chonetes cracowensis*, Eth.
3. *Pleurotomaria rotunda*, Eth.
4, 4 *a*. *Productus* or *Strophalosia*.
5. *Murchisonia carinata*, Eth.
6. *Natica* (*Naticopsis* ?) *harpæformis*, Eth.
7. *Griffithides dubius*, Eth.
8. *Spirifera* allied to *Sp. striata*, Sow.
9. *Productus longispinus*, Sow.

PLATE XIX.

Fig. 1. *Cyprina expansa*, Eth.
2. *Trigonia nasuta*, Eth.
3. *Crenatula ? gibbosa*, Eth.
4. Genus ?
5. *Nucula quadrata*, Eth.

PLATE XX.

Fig. 1. *Cucullæa robusta*, Eth.
2. —— *costata*, Eth.
3. *Nucula quadrata*, Eth.
4. —— *gigantea*, Eth.
5. *Leda elongata*, Eth.
6. *Tellina mariæburiensis*, Eth.
7. —— sp.
8. *Avicula alata*, Eth.

PLATE XXI.

Fig. 1. *Natica lineata*, Eth.
2, 2*a*. *Panopæa sulcata*, Eth.
3, 3*a*. —— —— *plicata*, Sow., var. *acuta*, Eth.
4. *Ammonites Sutherlandi*, Eth.

PLATE XXII.

Fig. 1. *Inoceramus marathonensis*, Eth.
2. —— *multiplicatus*, Stol., var. *elongatus*, Eth.
3. —— *pernoides*, Eth.
4. —— allied to *problematicus*, D'Orb.

PLATE XXIII.

Ammonites Beudanti, var. *Mitchelli*, Eth.

PLATE XXIV.

Ammonites Daintreei.

PLATE XXV.

Fig. 1. *Fenestella fossula*, Sow.
2, 2*a*. *Ceriopora* (?) *laxa*, Eth.
3. *Avicula Hughendenensis*, Eth.
4. *Pleurotomaria Cliftoni.*
5. *Homomya.*
6. *Pholadomya.*
7. *Myacites.*
8. *Tancredia.*

PLATE XXVI.—*Lepidodendron nothum*, Unger.

Fig. 1. Part of a branch, clothed with leaves.
2. Portion of the same magnified $2\frac{1}{2}$ times.
3. Part of a somewhat older branch, deprived of the leaves, and showing the bases somewhat larger than in fig. 1.
4. Portion of the same magnified $2\frac{1}{2}$ times.
5. Fruit-bearing leaf of *Lycopodium Gayanum*, Brongn. (from Brongniart's Hist. Vég. Foss. vol. ii. pl. xii. fig. 10 *c*.)
6. Fruit-bearing leaf of *L. nothum*, Ung., from branch fig. 1.
7. Dichotomously dividing branch, the upper part clothed with leaves; the lower without leaves, and showing the rhombic scars of the leaves.
8. Portion of another branch, showing the passage of the rhombic leaf-scars into the more compressed scars of the upper part: the scar of the vascular bundle is situated in the upper angle of the leaf-scar.
9. Part of a small branch, with rhombic scars, showing the scar of the vascular bundle as a line along the middle of each rhomb.

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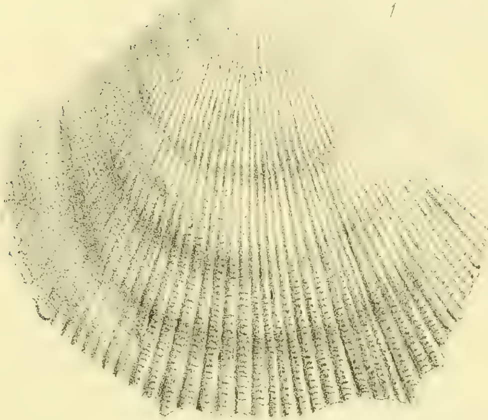

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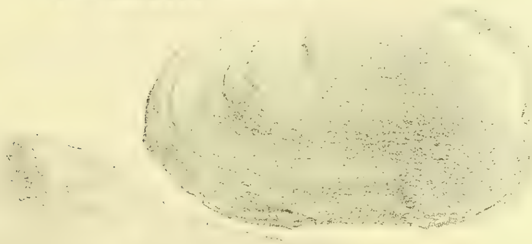

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C. R. Bone del. et lith.

M & N Hanhart imp.

QUEENSLAND FOSSILS.

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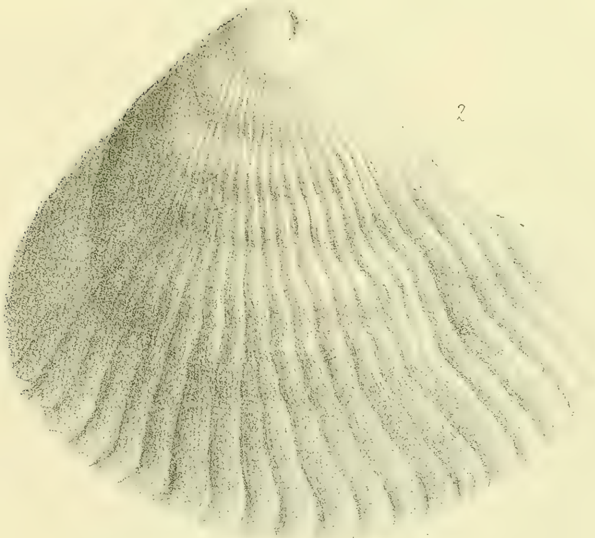

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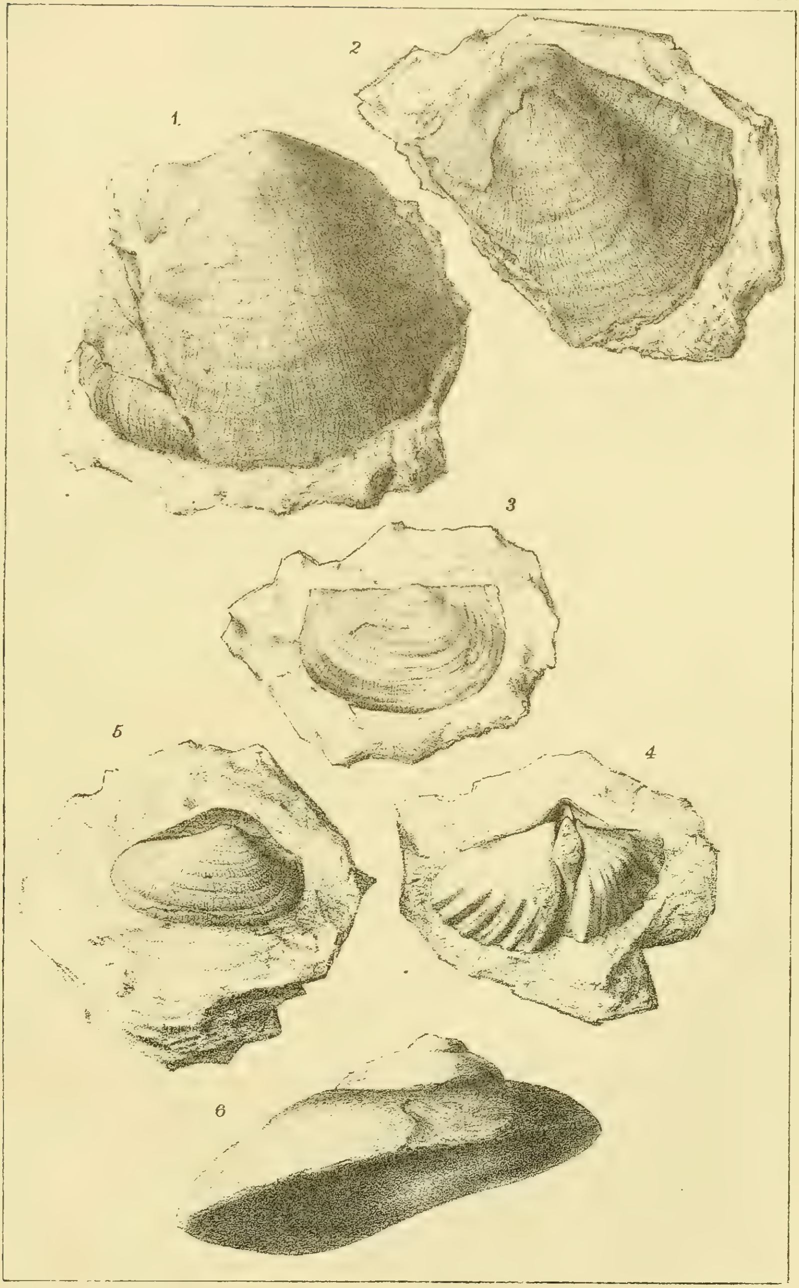

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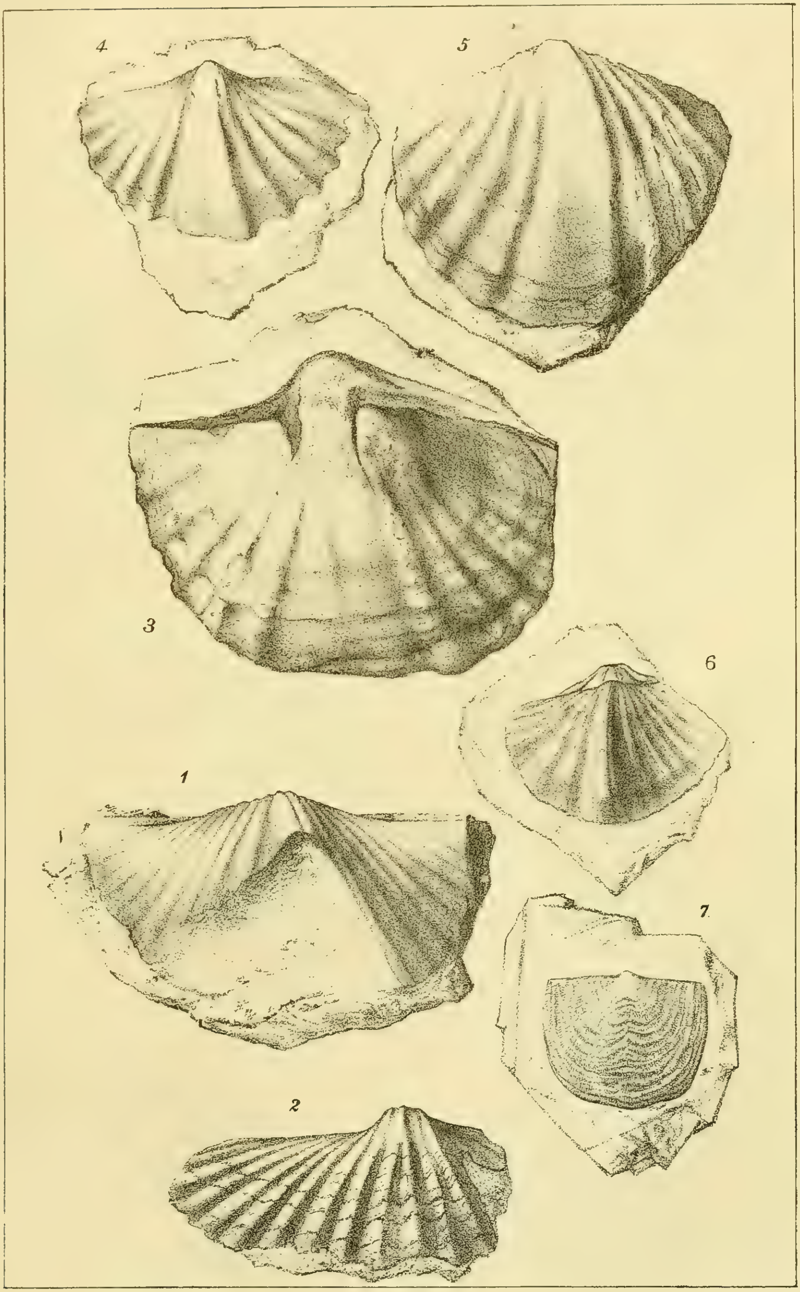

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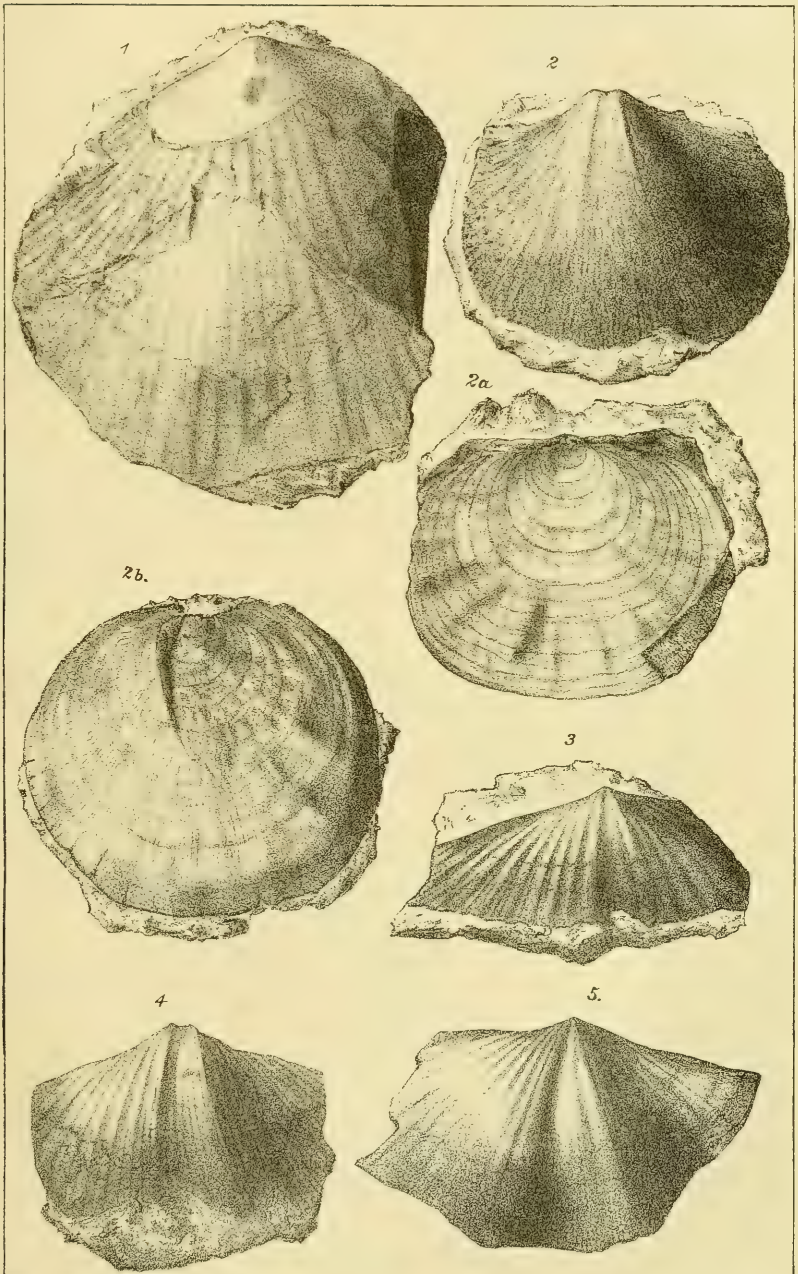

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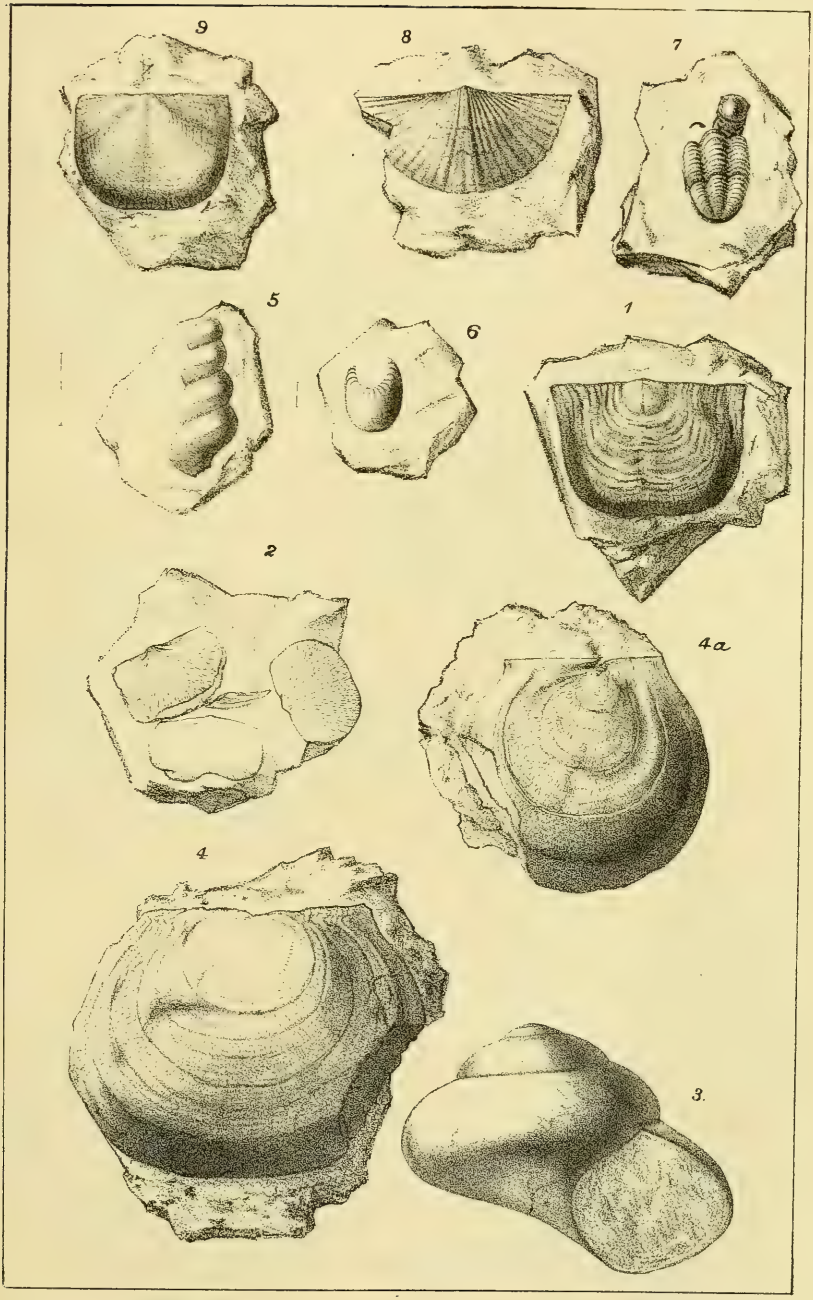

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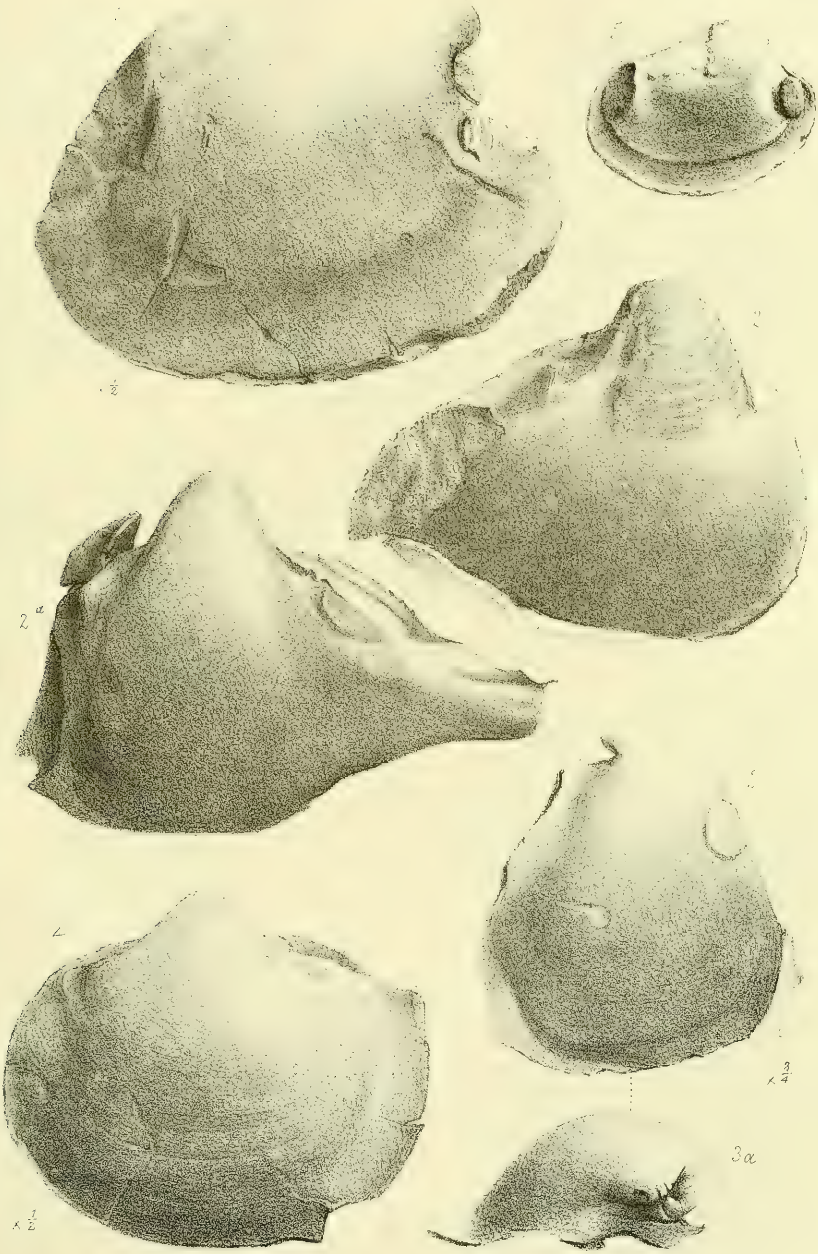

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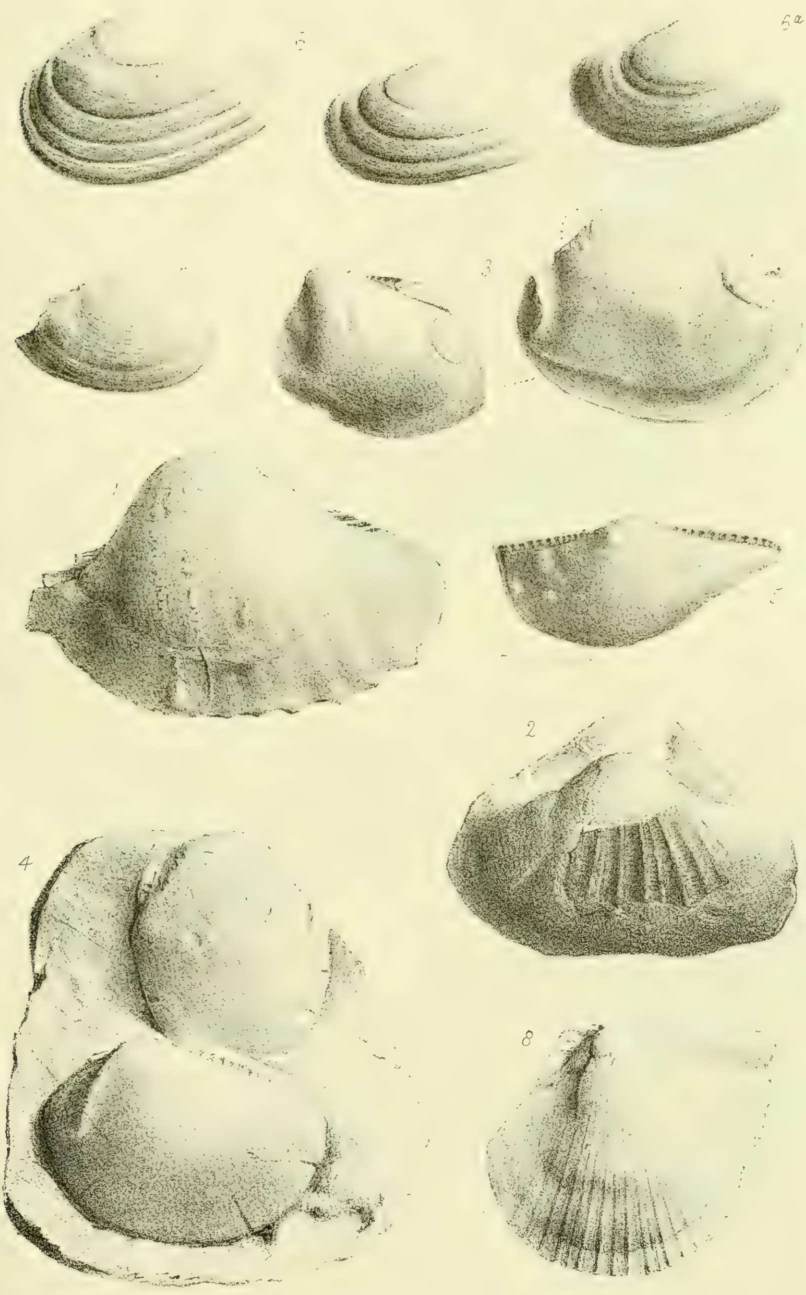
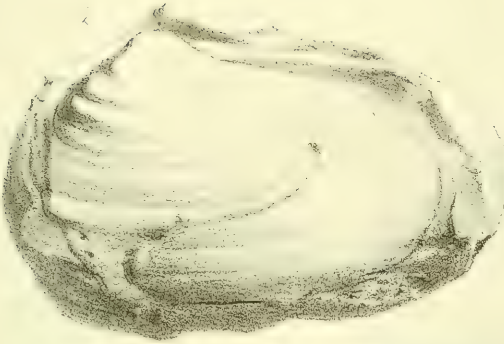


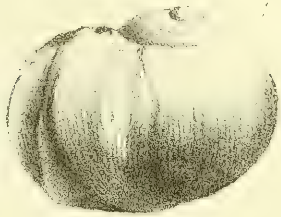
C.R. Bone. del. et. lith.

M&N. Hanhart. imp.

QUEENSLAND FOSSILS.

Quart. Journ. Geol. Soc. Vol. XXVIII. Pl. XXI.





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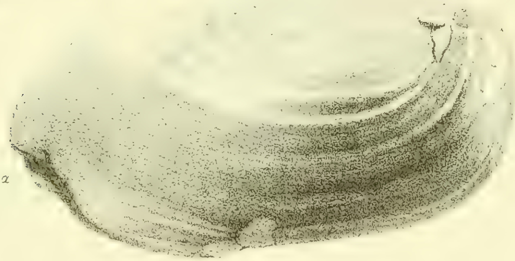

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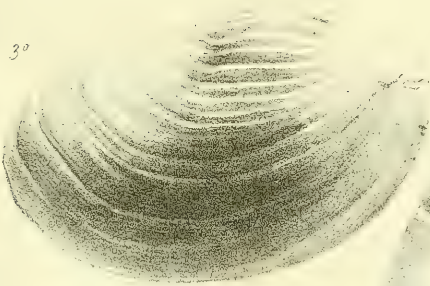

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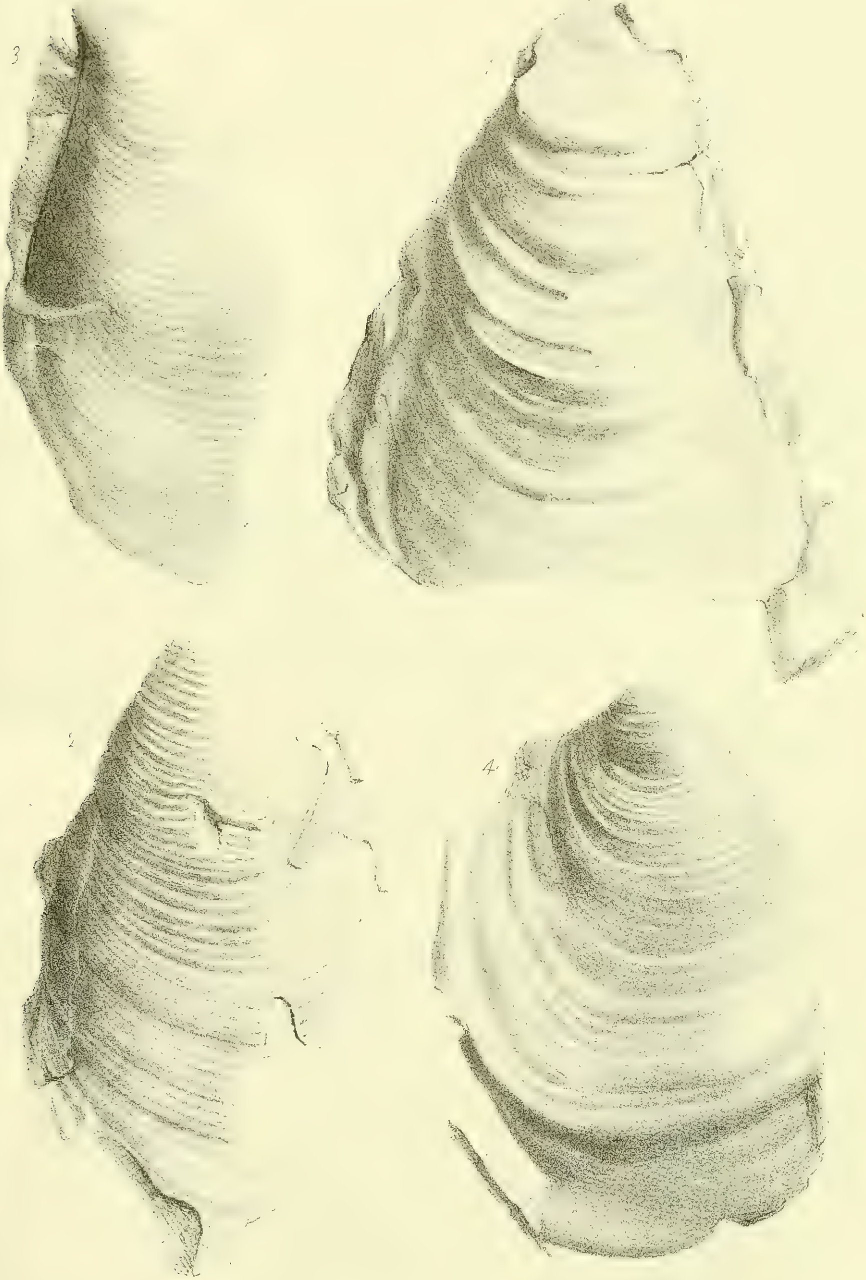
C. R. Bone del. et lith.

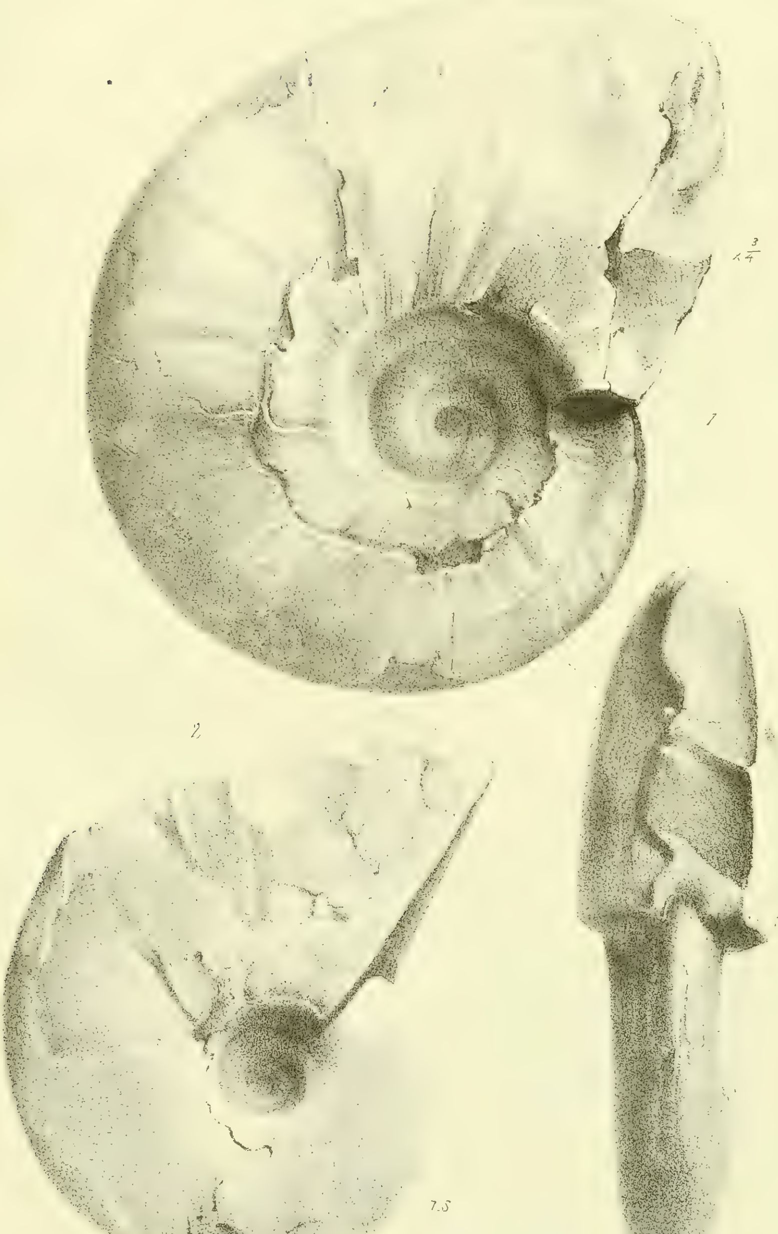
M. & N. Hanhart imp.

QUEENSLAND FOSSILS



C. R. Bone. del. et lith. M. & N. Hanhart. imp.

QUEENSLAND FOSSILS



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M & N. Hanhart. imp.

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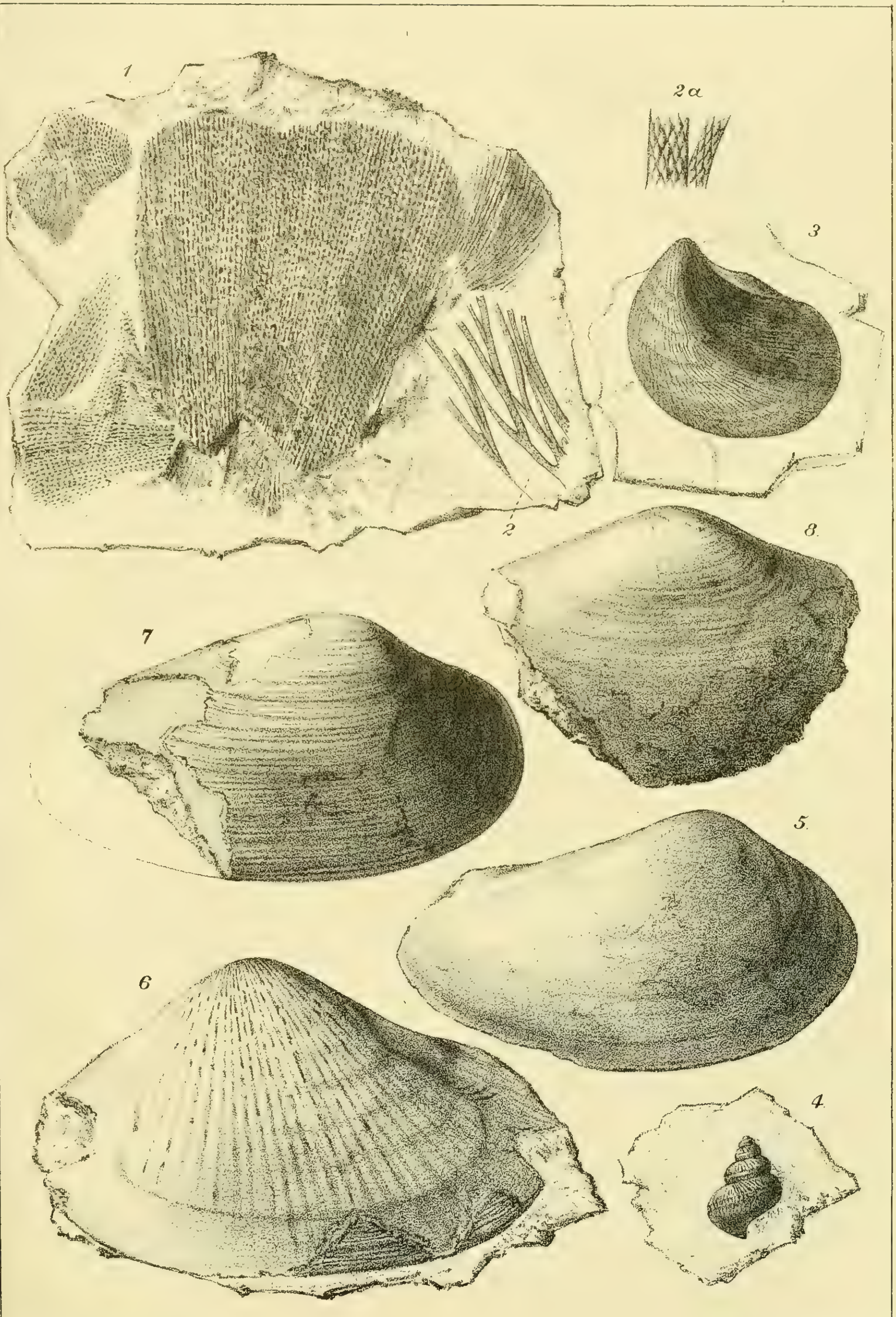
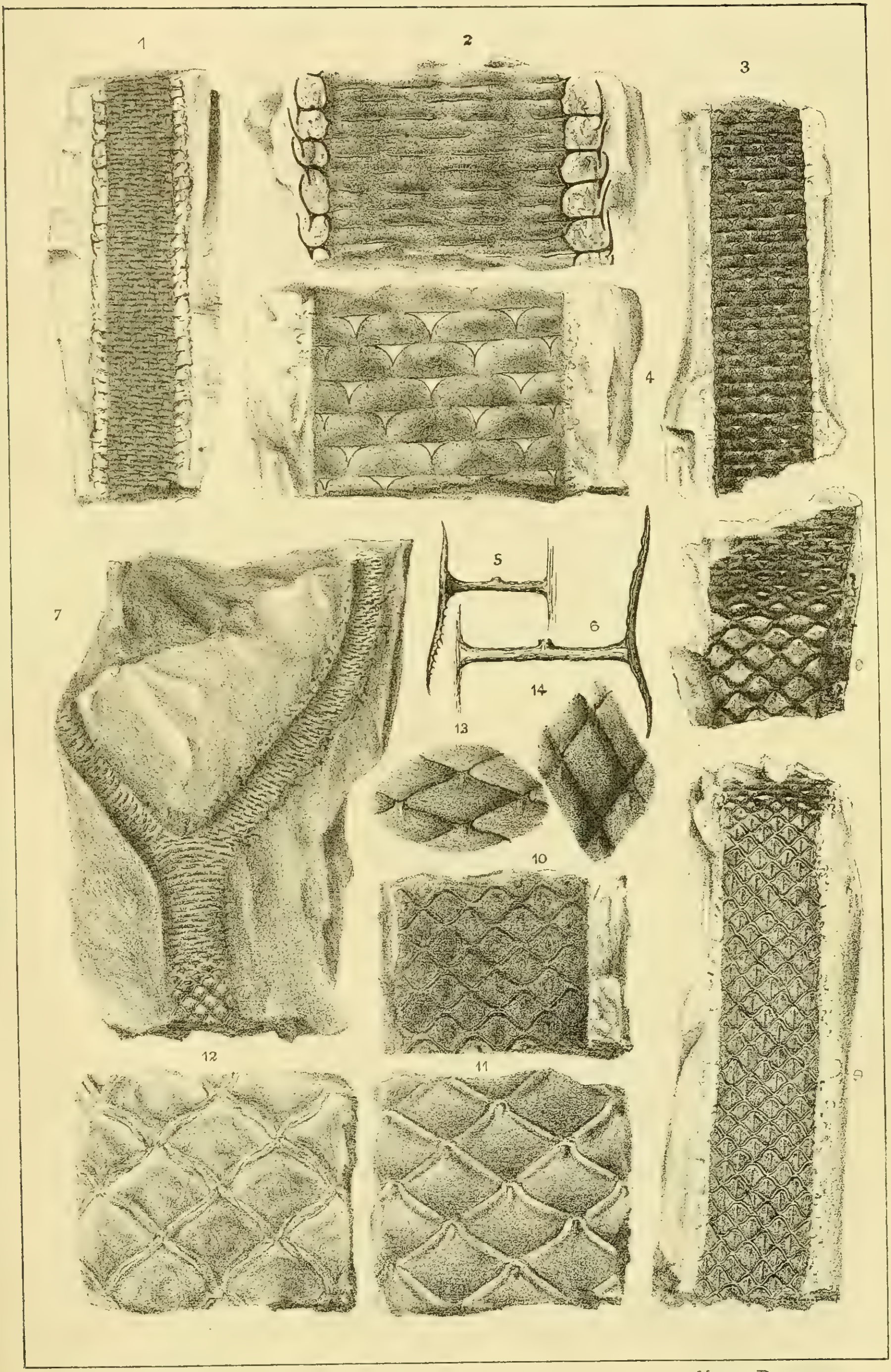


C.L. Griesbach del. et lith.

Mintern Bros. imp.

QUEENSLAND FOSSILS



D. Blair. del et lith

Mintern Bros. imp

FOSSIL PLANTS FROM QUEENSLAND.

D Blair del et lith.

Mintern Bros. imp.

FOSSIL PLANTS FROM QUEENSLAND.

Fig. 10. Part of a larger branch, with the vascular scar in the centre of the leaf-scar.
11. Part of a stem with large leaf-scars and apical vascular scar.
12. Leaf-scars without any vascular scar.
13. Leaf-scars compressed horizontally.
14. Leaf-scars compressed perpendicularly.

All the figures are natural size except 2, 4, 5, and 6.

Plate XXVII.

Fig. 1. *Sphenopteris elongata*, sp. nov.
2, 3. *Pecopteris odontopteroides*, Morris.
2 *a*. A segment enlarged, to show the venation.
4. *Cardiocarpum australe*, sp. nov.
5. *Cyclopteris cuneata*, sp. nov.
6. *Tæniopteris Daintreei*, sp. nov.

Discussion.

Mr. Etheridge mentioned that, among the fossil Mollusca exhibited from Queensland, there were about eighty species in all, thirty-nine of which were new. About twelve species were also found in the British area, some of them being of common occurrence in both countries. This was especially the case in the Palæozoic rocks, but also prevailed to a considerable extent in those of the Cretaceous period. The same similarity among fossils so widely separated in space was found among the fossil corals of Queensland and those of Europe. It was to be regretted that so many of the fossils are merely casts; but he still thought that they were capable of being properly figured, and the species determined.

Mr. Carruthers had examined the vegetable remains brought over by the author, which were of great importance. Some of those from the Devonian rocks appeared to be identical with species found in North America. From the remains of one of these, which he could not separate from one described by Dr. Dawson, *Leptophlœum rhombicum*, he had been able to reconstruct it in its entirety, of which he exhibited a drawing. The plant was lycopodiaceous; and its remains served to show that erroneous conclusions had been drawn as to the characters presented by the North-American specimens, which had been regarded as having a *Sternbergia*-pith. There were specimens also of *Cyclostigma*, of the stipes of ferns, and of a doubtful Calamite. With regard to the supposed *Glossopteris*- and *Tæniopteris*-epochs, which by some had been regarded the one as Palæozoic and the other as Mesozoic, he was not convinced that they could be distinctly separated, but thought rather that they might both belong to different portions of one great period. Systematically the two forms might be very closely related, the venation of the fronds on which the genera are founded occurring in two forms, which by Linnæus had been included in one genus, *Acrostichum*. He thought that neither was of a date earlier than Permian.

Mr. Smyth regretted that so many questions were brought forward in the paper that it was almost impossible to follow the whole of them. The connexion of the gold-bearing reefs with the igneous rocks seemed to him very remarkable. It had in former times been suggested that there was some limitation of auriferous deposits to Palæozoic rocks, and he wished to know whether the author's observations corroborated such a view, which appeared to him problematical. He commented on the value of foreign collections of fossils such as that exhibited, and called attention to the rich stores of that kind preserved in the museum of the Society, which would be found of great assistance by any one studying the geology of Australia.

Mr. DAINTREE, in reply, stated that in the West-Maitland beds *Glossopteris* was found distinctly underlying beds containing *Spirifera* and other distinctly Carboniferous species. He had no doubt of *Glossopteris* being in Queensland a purely Palæozoic form. He had been unable to trace any igneous action whatever over the whole of the cretaceous plains to the westward; and the absence of igneous or metamorphic rocks was further proved by the natives having to obtain the materials for their tomahawks by exchange from those nearer the coast. In the proximity of the dykes he had not found any signs of alteration of structure; but the occurrence of gold in the Devonian area was, according to his experience, limited to the close neighbourhood of the dykes.

Prof. RAMSAY remarked on the Desert Sandstone, and pointed out that, though stratigraphically of such importance, the amount of geological time it represented was probably but small. The changes, however, of which it bore evidence since Miocene times, were enough to strike the mind with astonishment, and to convey some idea of the great variations in the physical features of the surface of the world, even within the period during which possibly the human race had existed.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

May 8, 1872.

William Edward Balston, Esq., B.A., of Thornhills, Maidstone, was elected a Fellow of the Society.

The following communications were read:—

1. Notes *on* Atolls, *or* Lagoon-islands. By S. J. Whitnell, Esq.

(Communicated by Prof. Maskelyne, F.R.S., F.G.S.)

[Abstract.]

These notes are founded upon an examination of sixteen atolls in the Union, Ellice, and Gilbert (or Kingsmill) groups. The author is of opinion that, although the production of atolls is due to subsidence, a cessation of this subsidence is necessary in order to their emergence from the sea. He argues that, as the islands formed upon the reefs of atolls consist entirely of broken coral, shells, and fine sand, it seems improbable that such materials should accumulate upon a sinking surface; or if they did temporarily collect, owing to certain favourable conditions, they would soon be washed away again by the waves. At Funafuti (or Ellice Island) he noticed what he regards as signs of upward movement. On the weather side of the largest islet in this atoll there is a small lagoon (dry at low water) shut in from the sea by a wall, 20 feet high, of large masses of coral. The reef forms a narrow ledge, upon which the author saw compact masses of coral, *in situ*, rising 4 feet above low-water mark.

The author also mentions, as an indication of the mode in which these islands are formed, the furrowed appearance which some of them present. Of Atapu, or Duke-of-York Island (Union group), the shore, and of Peru (Gilbert group) the whole island, appear to be formed by a series of mound-like ridges, that nearest the sea forming the beach. They vary in width from 20 to 50 feet; and the furrows separating them are 4 to 6 feet deep. They consist of fine coral *débris*; and, from information which he received, the author considers that each mound is the product of a single gale, although it may be added to during subsequent rough weather.

The author also notices a freshwater lagoon, about three miles in diameter, on Quiros, or Gente-Hermosa Island, and states that the water was only very slightly brackish. There is no communication between the lagoon and the sea, although there are signs that the connexion must have been closed at a comparatively recent date. The water in the lagoon does not appear to be affected by the rise and fall of the tides; and the author thinks that its surface is above the sea-level. He indicates the difficulty of accounting for the presence of this body of fresh water in so small an island, and inclines to adopt for this and the neighbouring island of Lakena, which also possesses a freshwater lagoon, the hypothesis that they have originated from the craters of extinct volcanoes.

Discussion.

Mr. Thorp was acquainted with the atolls around the coast of Ceylon, and thought that the local traditions, untrustworthy as such sources usually were, might afford some evidence as to the date of their origin. The tradition in Ceylon was that the Maldive and Laccadive Islands had within the memory of man been connected with Ceylon. If they were so, the evidence was in favour of the a being one of subsidence.

Mr. D. Forbes, when in 1859 he spent some months in the Pacific, had been requested by Mr. Darwin to examine into the evidence as to the origin of these atolls by elevation, and had found that the asserted cases of the existence of masses of coral at a considerable elevation above the sea merely arose from blocks having been transported inland by the natives. Though, however, there was no evidence of elevation, it was still possible that such had in certain cases taken place, as there were still active volcanoes in this region. The freshwater lakes he attributed to the drainage of the islands.

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2. *On the* Glacial Phenomena *of the* Yorkshire Uplands.

By J. R. Dakyns, Esq.

(Communicated by Prof. Ramsay, F.R.S., F.G.S., &c.)

The Carboniferous hills that form the central axis and backbone of Northern England sink beneath the Triassic plain near the town of Derby. Between Derby in the south and Wensleydale in the north, this line of hills is broken through by the valleys of the Wye, in Derbyshire, and of the Calder and the Aire, in Yorkshire.

In Derbyshire and the part of Yorkshire south of the Aire basin, no glacial drift has been found on the eastern slope of the chain, save where the latter is broken through by the above-named valleys. Thus in Derbyshire plenty of drift occurs in the valley of the Wye and in that of the Derwent below its junction with the Wye, as if some of the drift that is so plentiful on the western slope of the Pennine chain had come eastward through the Wye valley; but north of the Wye none is found in Derbyshire on the eastern slope of the chain. Again, some boulders of transported rocks, granite, and other foreigners are said to have been found in the bed of the Calder; but no drift-deposits have been found in the Calder basin east of the anticlinal axis, save one patch of Boulder-clay at Mixenden, some miles above Halifax, quite at the edge of the driftless area. The boulders above mentioned would seem to have been washed out of the drift of Lancashire. On the other hand, the western slope of the Pennine range is everywhere thickly covered with drift nearly up to the level of the watershed. But when we cross the Oxenhope moors, from the basin of the Calder into that of the Aire, the state of things is very different. The basin of the Aire and the whole country northward is thickly covered with drift indifferently on the east and west.

The drift of Lancashire and Cheshire is considered to be marine, for the following reasons: in the first place, it contains far-transported rocks, such as granite; in the second place, it is prolonged through the Wye valley, while nowhere else is drift found on the eastern hills, thus showing it had floated through the gap.

I will now describe certain general phenomena in connexion with the drift of the Aire basin and the country northward, from which it will appear, I think, that the mass of it is due to land-ice.

In the first place, this drift contains no foreigners—that is, no stones that may not have come from the rocks of the basin where it is found. Thus in the basin of the Aire, east of Skipton, the stones are entirely Carboniferous grits, sandstones, and limestones, all which rocks occur in the basin of the Aire; while north of Skipton, on the edge of the great plain that stretches to the Ribble, a few small, much-worn Silurian pebbles are occasionally found, which have doubtless come from the Silurians of Ribblesdale.

Again, in Wharfedale we have nothing but Carboniferous rocks in the drift, with one exception: this is near Threshfield, where Silurian erratics do occur; but they are special to that locality, and are found where the valley, ceasing to be a narrow dale, opens out into a plain reaching as far as the Ribble. In the high dale the drift is entirely composed of local rocks.

It would seem, then, that whatever brought the drift was some agent acting locally. It was not, then, either ice floating from afar or necessarily a universal ice-sheet overriding the watersheds, though I shall presently give reasons for thinking there was such an ice-sheet.

Further, in Wharfedale and its affluents, in Wensleydale (as far as I know) and its affluents, the following phenomena are universal.

Wherever two large valleys join, there is a great pile of drift heaped up in the angle between them, on the gable end of the bounding hills. This is seen at the junction of Wharfe- and Littondales—again at Kettlewell, at the junction with the main valley of a large gill descending from Coverhead, and in other places—also above West Burton, on the gable end between Walden and Bishopdale. This points unmistakably to glaciers descending the two valleys, and throwing down together their inner lateral moraines. Moreover, the rock is apt to be moutonnée where the pressure of a glacier would be greatest. One case, in particular, I can mention: just above the hamlet of Kilnsey is a conspicuous scar of solid limestone; the northern face of this rock is beautifully smoothed; and this is just where the Wharfedale glacier would press that coming down Littondale against the side of the valley. We should doubtless see more polished and scratched surfaces, were it not that limestone, when not covered with clay, yields so rapidly to the action of the weather; but we do sometimes find scratches and grooves, and they are always along the valleys. There is an excellent example, for instance, of grooved and polished limestone preserved under a bed of clay near Kettlewell.

Another general phenomenon is the following. Where a barrier of rock crosses a valley, the drift is piled up in mounds against and over the rock, as if deposited by a glacier against a barrier; and above such a barrier there is generally a wide spread of alluvium, as if a lake lying in a rock-basin had been silted up. This is nearly, if not quite, universal.

Again, where we have such a spread of alluvium, we do not see the solid rock in the bed of the stream between the two ends of the alluvium; when we do get the rock in the stream, it is near the beginning or the end of the alluvium, and there, too, a mound of drift crosses the valley. This, again, points to rock-basins and local glaciers depositing a terminal moraine against the rock barrier. It is a difficult matter positively to prove the existence of a rock-basin; but when, over and over again, we find a spread of alluvium above a rock barrier, and that no solid rock shows in the course of the stream through the alluvial flat, save at its ends, the beds all the while retaining their usual dip, this amounts by a cumulative argument nearly to a proof thereof.

A great deal of the drift is as angular as ordinary moraine-matter might be expected to be; but a great deal of it is also composed of rounded pebbles, well scratched; and yet these two cannot be separated from one another; and the rounded and scratched drift has often the characteristic shape of moraine, whether terminal or lateral. But rocks riding on the surface of a glacier, and shed therefrom, will be neither rounded nor scratched. The latter kind of drift, then, did not so come. But rocks sticking in the bottom of a glacier will be both rounded and scratched, and the more so the further they have travelled. So we must consider many of our moraines to have been shed from the body of the glacier. It struck me, too, that the further we go from the parent hills, the more generally rounded and scratched does the drift material become. This is again an argument in favour of the glacier origin of the drift.

There is another point to which I wish to direct the attention of geologists, that we may learn whether there is any thing in it or whether it is merely a local accident. I was very much struck with it when, three or four years ago, I first became acquainted with the great drift-area. It is this: the drift is very often found entirely on one side only of a valley, and that always the same side with reference to the source and origin of the drift, viz. on the lee side of hills, as drifted snow or any other drifted material. I will give some examples. The drift of the Aire basin doubtless came from the north and north-west. Now the south side of the Aire valley near Keighley is comparatively free from drift, while the north side is thickly covered with it. Again, take the Worth valley, which runs to the N.E.; the east side is free from drift, while the west or lee side is thickly covered. The same appeared to me to be the case with Wharfedale where it runs east and west, viz. that the north side was thickly covered, while the south was free. If it should turn out that this is any thing more than a local accident, it points to a universal ice-sheet and to the drift being moraine profonde deposited thickly on the lee side of hills while the ice-sheet passed over it, dropping it in its course, whereas on the exposed side the ice, as it ascended the slope, swept every thing before it. Of course, such valleys as lay in the direction of the ice-flow will not have this contrast of sides.

Besides the scratched gravels, we have also in certain places mounds of water-worn gravels arranged in confused heaps, often enclosing hollows, known by the name of Kames or Eskers. These kames bear a distinct relation to the valley; they occur at certain parts only of the valley, and were evidently deposited in the bottom of it; they form irregular mounds, sometimes quite blocking up the valley; they consist of stones that have been once scratched, but whose scratches have been worn off, doubtless by the action of the water in which the kames were deposited; so that the kames are either rearranged drift, or consist of drift deposited in the sea (for lakes are here out of the question) and which got its scratches effaced in the process of deposition. That the pebbles were once scratched is shown by the faint traces of scratches that sometimes occur.

From the way in which kames pass gradually into scratched gravels, and from the definite position they occupy in the valley, it seems to me probable that in many cases kames are merely the result of moraines deposited in the sea instead of on land.

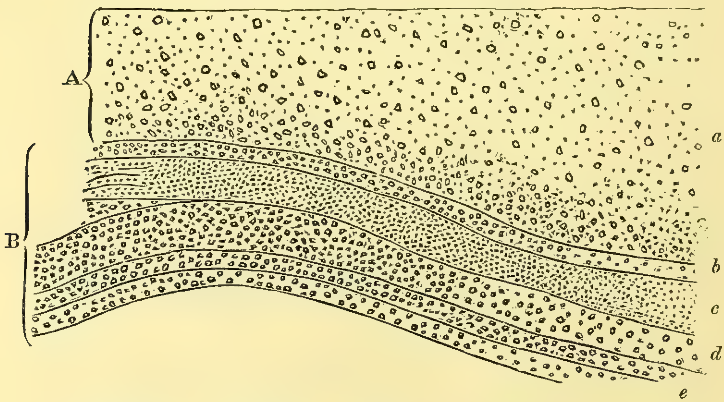
It seems to me that the long straight ridges that run across hills without any reference to contours, and which are also called kames, are something quite distinct from the irregular valley-mounds just described.

That these valley kames are due to sea-action is also shown by the fact that the cross-bedding of the sand dips up the valley as well as down it. This implies a current setting up the valley. When the land stood low enough for the kames at Bingley to be deposited, the valley of the Aire would have been a frith, through which the tide may have set in opposite directions alternately, and thus the sand might be bedded both up and down dale. I can see no other way than by a tidal current setting backwards and forwards through a strait in which sand and gravel can be deposited with a dip both up and down dale.

The close connexion of kames with ordinary scratched drift is well seen in the vale of York. The western side of that vale consists of low undulating hills of drift. This drift is sometimes a well-scratched deposit of typical Boulder-clay, containing intercalated seams of fine sand and gravel, or a deposit of scratched pebbles too stony to be called Boulder-clay; the true Boulder-clay and the gravel passing gradually into one another. At other times the beds consist of stratified gravel, with here and there a faint trace of scratches that once existed but are now all but effaced. These gravels have the characteristic shape of kames; they either form long ridges, nearly straight, or are arranged in confused heaps surrounding hollows; but the scratched and the unscratched gravels are quite inseparable from one another.

In some gravel-pits near York, the structure of these kames is well seen. There we have, at the Coplesham gravel-pit, the following section:—

Section in Coplesham Gravel Pit.



a. Strong clay. *b.* Gravel. *c.* Sand. *d.* Gravel. *e.* Gravel.

The upper part (A) consists of a stiff, brown, unstratified clay containing a few scattered pebbles in its upper part, but choke-full of stones in its bottom, where it rests on the lower bed (B), which is a well-stratified gravel and sand arranged in the shape of a ridge, the beds dipping away on both sides from the crown of an arch.

I saw no scratched stones here; but corresponding stratified gravels on the other side of the Ouse contain numerous well-glaciated boulders and pebbles in their lower part, where they seem to be passing downwards into true boulder-gravels.

The stones in the clay (A) were too dirty for me to see whether they were scratched or not; but it has the look of a true Boulder-clay. As far as the York sections go, then, the kames lie between two Boulder-clays; they would thus seem to be the equivalents of the middle drift, sands, and gravels of Lancashire.

They contain mammalian remains.

I think, then, that there is evidence for the following series of events:—At one time the Yorkshire hills were covered with continental ice, as Greenland is now; the vale of York was under water, and formed an arm of the sea into which the great glacier descending from the hills discharged its moraines, which were rolled about by the tides and deposited as kames; and subsequently, when the ice no longer reached the coast, the previously deposited drift would be rearranged by the tidal currents into kames; perhaps the land may have sunk gradually, so as even to bring new drift material within the action of the sea. At all events the land at one time stood low enough (say 400 feet below its present level) to allow of the valley of the Aire becoming a strait through which the tide played.

The climate ameliorated, perhaps as the land went down, till the universal ice-sheet vanished; but the great dales, such as Wharfedale, Wensleydale, Ribblesdale, &c., and their affluents had each a glacier descending it; these debouched at first in the sea, which filled the dales as the sea does the Norwegian fjords, to the height of 600 or 700 feet; subsequently the glaciers retired from the sea-level and finally vanished.

Why during all this time there should have been no glacial deposits formed on the eastern slope of the Pennine hills south of the Aire basin, is a very puzzling matter. I can only pretend partially to account for it by the following considerations. In the first place, the further south we go, of course, *cæteris paribus*, the milder the climate becomes; and every mile makes some difference. In the second place, though one wonders why, if there were glaciers descending from Whernside 2300 feet high, there should not also have been glaciers on Kinder Scoot, 2000 feet high; yet, though the extreme points in the southern country are nearly as high as some of the highest hills in the north, the general level of the country is lower, and there is also not so much high ground superficially. And lastly, when the land stood about 1200 feet lower than it now does, (and the Lancashire drift in places reaches nearly as high as this), what remained above water would be such a narrow belt of land that there may well have been no land-ice. At the same time the submergence was not great enough to allow ice to float from the northern area laden with drift, as the watershed between the Aire and Calder is 1350 feet above the present sea-level. Perhaps the submergence was not even as great as 1200 feet in the Aire basin: we have evidence, in deposits of sand on the hill-side, of a submergence of 1000 feet; but that is the most I know of.

DISCUSSION.

Prof. RAMSAY agreed with the author as to the existence of these rock-basins in the Yorkshire area, and as to the absence of marine drift on great part of the slope of the Pennine chain. The terminal moraines had to some extent become obscured by the washing-in of soil by rain; but their ancient existence in many of the Yorkshire valleys was indisputable. The features of the country were, moreover, in many instances such as could not be reconciled with the deposition of the drift by marine action.

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3. *On a* SEA-COAST SECTION *of* BOULDER-CLAY *in* CHESHIRE. By D. MACKINTOSH, Esq., F.G.S.

THE threefold division of the great north-western drift*, established by Professor Hull, extends into the peninsula of Wirral, if not further south, in Cheshire; and I have found it strongly marked near Padeswood station, Flintshire†. To the south of the Mersey, the Lower Boulder-clay becomes very attenuated or patchy, while the upper or brick-clay becomes thicker or more generally diffused. In many places the upper clay is underlain by extensive and persistent deposits of non-glacial sand and gravel (attaining at Gresford a thickness of 150 feet)‡, which rest on rock, excepting where they are underlain by a few remnants of the lower clay which escaped denudation. In other places the upper and lower clays coalesce. One of the best instances of the two clays in contact, with their distinctive characteristics still preserved, may be seen at Dawpool, on the N.E. side of the estuary of the Dee. From Parkgate the lower clay (with large boulders), under a thin covering of the upper clay, may be traced nearly all the way to the Dawpool cliff-section§, which reaches about 50 feet in height, and extends for a distance of three miles. In the part of this section S.E. of Dawpool cottage, where it has not been obscured by talus or the effects of rain, the upper may be seen to be separated from the lower clay by a line (either winding or straight), which in some places is so sharply defined as to indicate that the top of the lower clay had been cleanly

* This classification does not include the comparatively local and more ancient blue clay, the relative position of which I have traced through the West Riding of Yorkshire, Cumberland, and along the coast of North Wales.

† Here some portions of the middle gravel and sand have been converted into "rockery" by the percolation of water charged with carbonate of lime from the overlying clay, similar to what may be seen in many places along the east coast of the Irish Sea. (See paper by the author on the Drifts of N.W. Lancashire, Quart. Journ. Geol. Soc. vol. xxv. p. 411.)

‡ Here, as in many other places, the sand and gravel rise to the surface from beneath capping patches of the upper clay. Near Oswestry, the sand and gravel form eskers, in some instances capped with the upper clay. Very striking eskers, enclosing hollows with no outlet, may likewise be seen near Oakmere, and in other parts of Cheshire.

§ I visited the Dawpool cliffs four times, at intervals, with the object of finding fresh faces exposed by clay-slips and the action of high tides.

shaved off before the upper clay was deposited. Neither the fractures of the latter, nor the light-grey or bluish substance (*carbonate* of lime) with which they are faced, descend into the lower clay. This substance gives a character to the upper or brick-clay all round the shores of the Irish sea as far north *at least* as Barrow, and as far west as, if not further than Colwyn. In the lower clay, at Dawpool, a very few instances, on a small scale, of grey partings may be detected; but they consist of *sulphate* of lime, and can often be traced to the decomposition of fragments of gypsum imbedded in the clay.

On breaking into the upper clay, its colour in the Dawpool section is a peculiar brown; elsewhere its colour (apart from the grey or blue facings) is often reddish or reddish-brown, especially when seen from a little distance. The lower clay is rather darker and brighter, and varies from a chocolate-brown to a madder-brown. The upper clay contains few stones, and still fewer boulders. In the lower clay the stones increase in number downwards until it is nearly pack-full of them towards the lowest visible part of the section. The structure of the upper clay (with the exception of the far-travelled stones) indicates nothing further than ordinary sedimentary deposition. The lower clay is charged with grit and stones from the size of a pin's head up to good-sized boulders and (at the base of the deposit) enormous blocks. Its structure exhibits no traces of its component parts having been assorted by the ordinary action of water, excepting the frequent occurrence of a series of horizontal and parallel cracks, which would seem to point to successive deposition*. The lower clay is harder than the upper. It resists the softening influence of water, and stands after being undermined. It has even admitted of caves being excavated in it by the sea. The upper clay will not stand when overhanging, or indeed for any considerable time at an angle of more than 25° or 30°. It is so easily softened by rain-water that its presence in railway cuttings can generally be safely inferred from the frequent appearance of landslips. In the upper clay the fractures are vertical; in the lower they cross each other obliquely, and are intersected by gaping parallel joints which are inclined from the perpendicular at an angle of from 15° to 20°.

The lower clay is as much a glacial clay as any I have yet seen. It is evidently on the same horizon with the Lower Boulder-clay which at intervals may be seen along the coasts of the Irish Sea from Workington to Anglesea. It differs from the *pinnel* of Furness and the central parts of the Lake district, in the pinnel being still more charged with stones, in these stones being very much less polished and striated, and in the pinnel exhibiting a tendency to a curved or arched stratification.

The majority of the stones in the lower clay at Dawpool are more or less glaciated on one or two sides, or all round. The striæ in many instances run parallel; in others they cross each other at

* It likewise contains seams and pockets of sand, and, in one or two places, may be seen graduating into, or replaced by, a nearly stoneless clay or loam.

various angles. The upper side of a stone (as it lies in the clay) is quite as often flattened and scratched as the under, so far at least as I had an opportunity of observing. The longer axes of the stones are not in parallel lines; and stones and large boulders may often be seen glaciated, not only lengthwise but in a directly or obliquely transverse direction. On the whole the stones in the lower clay of Cheshire are less uniformly striated than in the upper or brick-clay.

The lower clay in the Dawpool section (and, I believe, in most places) contains a considerably larger proportion of local materials than the upper. Among the small stones may be found much local Triassic sandstone, marl, gypsum*, &c.; and the matrix in some places resembles so-called marl. The character of the erratics in the lower clay is likewise to a great extent peculiar. For instance, it is here full of decomposing greenstone, while little if any of this rock is found in the clay above†. The proportion of large boulders in the lower is much greater than in the upper clay; and it is worthy of remark that these boulders, owing to their consisting of rock which, *in situ*, breaks up into large blocks, would give a very different relative percentage from that which would result from a classification of the smaller stones. Instead, therefore, of attempting any such classification, I counted the number of large boulders of different kinds of rock at a spot where many had been collected from the beach, to facilitate a passage from the base to the top of the cliff-line; and the following is the result:—

	Number of Boulders.
Greenstone	48
Criffell granite	28
Felstone	16
Felspathic breccia	11
Felspathic porphyry	10
Eskdale granite	10
Upper Silurian grit	2

Among the smaller stones Silurian grit and argillite predominate. In addition to these rocks there are several kinds of granite of unknown parentage, Ennerdale (and Wastdale?) syenite, vein-quartz, carboniferous limestone, numerous chalk-flints§, &c. &c.

* The fragments of gypsum are often attached to bits of hard marl or shale, thereby proving that they have been transported, and not formed by chemical action in the clay. Some of them are striated.

† I do not recollect seeing any of this greenstone in drift to the west of the Duddon, and am at a loss to ascertain its parentage. The zone it occupies in Cheshire (and, I believe, Lancashire) is narrow from E. to W., if we except a few stray fragments.

‡ The fellows of these boulders may be seen scattered along the beach to some distance beyond Dawpool Cottage, and S.E. as far as Parkgate.

§ I sent a specimen of these flints to Professor Ramsay, who pronounced it to be a true chalk-flint, and stated that they are likewise common at Aberystwyth.

Discovery of Sea-shells in the Lower Boulder-clay.

For some time past the existence of sea-shells in the upper or brick-clay of Cheshire and Lancashire has been well known to local geologists; but, with the exception of two species found by Mr. De Rance in the Lower Boulder-clay at Blackpool, I was not aware that any shells might be dug out of solid parts of this clay, in a cliff-section exhibiting a clear sequence of the two clays, until I visited Dawpool*; and I am not sure that the attention of geologists has hitherto been specially directed to the fact that a thoroughly glacial clay (as much so as many clays referred to the action of land-ice) may contain not only numerous fragments of shells, but many nearly perfect, and some, I believe, quite perfect specimens†.

APPENDIX.—LIST *of* SHELLS *from the* LOWER BOULDER-CLAY *of* DAWPOOL. By J. GWYN JEFFREYS, Esq., F.R.S., F.G.S.

BIVALVES.	UNIVALVES.
Leda pernula.	Littorina littorea; fragment.
Cardium echinatum; fragment.	Lacuna divaricata.
—— edule; numerous fragments.	Turritella terebra; several fragments besides a nearly perfect specimen.
Astarte borealis; two fragments.	Purpura lapillus; fragment.
—— sulcata, var. elliptica.	Nassa reticulata; fragment.
Mactra solida.	Buccinum undatum; two fragments.
Scrobicularia alba; fragment.	Fusus antiquus; two fragments.
Tellina balthica; numerous fragments.	

In all, 15 species.

All these evidently come from a beach-deposit, and agree with the Posttertiary shells from Moel Tryfan, the Severn valley, and Macclesfield. One of the species (*Astarte borealis*) is arctic or peculiarly northern, and does not at present live in the British seas, although it occurs in every Glacial and Postglacial bed. The most southern locality for this species, to my knowledge, is Kiel Bay in the Baltic‡.

* I have since ascertained that a *Turritella* previously brought from Dawpool by a very promising young geologist, Mr. W. Shone, jun., of Chester, was taken by him out of the solid lower clay.

† A number of the shells, including *Turritella terebra*, which I sent to Mr. S. V. Wood, jun., and afterwards (in two lots) to Mr. Gwyn Jeffreys for inspection, and which I dug out of parts (near the base) of the hard, stony, Lower Boulder-clay cliffs at Dawpool, were almost perfect.

‡ [Mr. Isaac Roberts, F.G.S., of Rock Ferry, has found 18 species of shells in the upper or brick-clay around Liverpool and Birkenhead (see 'Proceedings of the Liverpool Geol. Soc.' 1870–71); and Mr. Shrubsole, of Chester, has found 4 additional species in the same clay, making 22 species in all—namely, *Turritella terebra* (*communis*), *Cyprina islandica*, *Fusus islandicus*, *Aporrhais pes-pelecani*, *Trophon clathratus*, *Tellina solidula* (*Tellina balthica*), *Natica* sp., *Nassa reticulata*, *Purpura lapillus*, *Cardium edule*, *Cardium echinatum*, *Ostrea edulis*, *Pecten opercularis*, *Littorina littorea*, *Lutraria* sp., *Mactra* sp., *Buccinum undatum*, *Dentalium entalis*, *Murex erinaceus*, *Mytilus edulis*, *Lucina borealis*, *Psammobia ferroënsis*. Five of the species I found in the lower clay at Dawpool do not appear in this upper-clay list, namely *Leda pernula*, *Astarte borealis*, *Astarte sulcata*, *Scrobicularia alba*, and *Fusus antiquus*.—D. M.]

NOTE *on the* SHELLS *from the* LOWER BOULDER-CLAY *of* DAWPOOL.
By SEARLES V. WOOD, jun., Esq., F.G.S.

The shells are far less fossilized than those from our East-Anglian glacial beds and those from the Bridlington bed, and are all common shells of the British littoral region*. The Lower Boulder-clay from which they come I regard as belonging to the latest part of the Glacial sequence—later, that is, than the newest of our East-Anglian beds. The *upper* clay of Dawpool cliff (which is the same as the apparently uniform deposit of Upper Boulder-clay which extends through the lower grounds of North Wales, Cheshire, and Lancashire) seems to me not improbably the same as the Hessle clay of Yorkshire, which is obviously a deposit due to a postglacial (partial) resubmergence subsequently to the general emergence of the country from the glacial sea, and its reoccupation by the great mammalia.

DISCUSSION.

Prof. RAMSAY remarked, with regard to the Bridlington beds which had been cited, that they were probably preglacial, and not glacial. He thought that eventually it would be proved that during the Glacial Period there had been several oscillations in this country both in level and in temperature. With respect to temperature, the calculations of Mr. Croll showed the extreme probability of such variations being due to astronomical causes; and these were best illustrated by reproducing his figures in the form of a diagram showing the curves and oscillations of temperature.

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4. *On* MODERN GLACIAL ACTION *in* CANADA.
By the Rev. WILLIAM BLEASDELL, M.A.

(Communicated by Principal Dawson, F.R.S., F.G.S.)

SECOND ARTICLE.

FURTHER inquiry into the action of ice in Canada furnishes new facts illustrating the powerful effects of this agent in changing or modifying the Boulder-drift surfaces of the country lying over the Silurian strata, even during the period of human observation; and if so, how much more of change must have been effected in this way during that comparatively long period which, as far as Canada is concerned, may be designated prehistoric, when it lacked observers to note, and a written language to record, those changes which must have occurred in the bygone centuries of its existence in its present form, and subject to the same powerful glacial agencies and climate? In addition to the facts furnished to the Geological Society, and kindly received by it, in my previous paper †, I am now in a position to lay before the Society further evidence of this nature.

At the head of that arm of Lake Ontario named the Bay of

* [The species of shells I sent to Mr. S. V. Wood, jun., did not include all those above named by Mr. Gwyn Jeffreys.—D. M.]

† See Quart. Journ. Geol. Soc. vol. xxvi. p. 669.

Quinte, the Canadian river Trent discharges its waters at the village of Trenton; and a mile above the latter the lower or Frankford Rapids terminate. These rapids extend for about nine miles up the river, from this point to a mile above the village of Frankford, where there is again deep and navigable water. Between these two points the river runs over a limestone bed of the upper Trenton series of the Lower Silurian rocks, and the rapids are thus formed. At intervals small islands exist in what are sometimes designated as the Nine-mile Rapids. These tend consequently to increase the force of the stream by the impediments they present to its course. The islands are thinly strewn with a gravelly soil, and are mostly covered with trees, of a similar character to those on the river's banks, and with low brushwood, in which the Canadian wild grape (*Vitis vulpina*) luxuriates in particular spots.

About six miles from Trenton there was an island known by the name of Fidlar's Island; and here the effects of glacial action in the shape of ground-, anchor-, or pack-ice have recently become conspicuous. This island, once nearly sixty feet in length, has disappeared within the last eighteen months. All these islands lie, for obvious reasons, lengthwise in the stream; and the widest portion of the island in question may have been twenty-five or thirty feet in width. In the winter of 1869–70 the anchor-ice had so acted upon the surface of Fidlar's Island, and on its former site, as entirely to remove it and leave the subjacent rock entirely bare. And in the month of April 1870, when the waters of the Trent were unusually high from the melting snows of the region which it drains (at least, with its tributaries, 150 miles in extent), a large portion of the upper surface of this island came floating down on the face of the stream, and was seen at the village of Trenton below, with the trees and bushes on it in the upright position in which they grew.

Recently some observations on Ground-Ice and its Results, by Henry Landor, Esq., M.D., Superintendent of the Malden Asylum in this province, and communicated to the Entomological Society, London, Ontario, have been kindly laid before me by the Rev. C. J. Bethune, M.A., Principal of Trinity College School, and our most distinguished Provincial entomologist. This essay contains some most valuable and, I believe, philosophical remarks on the formation of ground- or anchor-ice in the rivers and streams of Canada. I insert the remarks of Dr. Landor, as published in a local organ, and issued by the Entomological Society, in illustration of the phenomenon under consideration:—" When the thermometer falls to 10° of Fahrenheit, ground-ice begins to form, but it is not at that temperature long adherent to the bottom. As soon as the sun rises, it rises and floats away in great abundance of small light porous portions of ice, covering, for the most part, the centre of the stream. But when the thermometer is at zero, the ice adheres to the bottom, and it is most apparent where the stream is most rapid. It is then most abundant where there is no surface-ice; there is none where the surface is frozen over. Depth of the stream, at any rate to six feet, does not prevent the formation of ground-ice; for it is seen abundantly on the bottom of the St.-Lawrence Rapids, and at the Tubular Bridge, Montreal, which affords a favourable point for observation, before the surface is frozen over. As the frost continues, the ice at the bottom thickens. It is tubular, or honeycombed, in the direction of the current; and the water pours through the tubes. It is rarely solid, but is so after long continuance of hard frost. It adheres to the stones at the bottom, or to the ground itself, and it remains anchored until its power of flotation enables it to rise to the surface and carry its anchor with it. It comes to the surface with stones attached to it. These stones, of course, bear a proportion to the mass of ice. When the mass is small, the stones it raises are small, and are only pebbles; but when the mass is large) and it is often a large mass that rises to the surface) it brings adherent to it large stones, deserving to be called small boulders. The mass floats away down the stream to the next part of the river that is frozen over at the surface. There it becomes frozen in with the mass of surface-ice, and in a very few hours loses its porous condition altogether." Such is the valuable testimony of a close observer in these matters, showing how this powerful agent is now acting from year to year in producing such changes on the surface of the earth as those of Crab Island adduced in my former paper, and Fidlar's Island in the present one. Dr. Landor also speaks of having seen in the small rivers that form the Canadian river Thames "a vast number of pebbles and stones, as big as a foot in diameter, carried away by ground-ice," and also of observing "the ice rise with stones attached." I might add to what has been already advanced from this valuable essay on this head; but I trust that at some subsequent period the author may lay the results of his observations on these matters before the Geological Society; for I believe them well worthy of its attention.

A visit just made (at the time I write) to the locality of Fidlar's Island reveals a rapid, surging up with white foam, and the water thus bounding over its site, whilst between it and Flat Creek Island, about 200 yards lower down the stream, a new shoal has been formed, probably by a portion of the *débris* of the former island. A mile lower down the river is Patrick's Island, which furnishes evidence that the same causes are operating extensively there, as it is greatly reduced in size, and glacial action has almost deprived its surface of soil—two detached groups of trees being all that now remains of it. Before long a shoal or a rapid will be all that remains to mark the site of Patrick's Island.

Another remarkable example of glacial action in Canada is the removal of Salmon Island, the history of which has but recently come under my notice. At the junction of the Bay of Quinte with Lake Ontario there is an island of some magnitude and well settled with inhabitants, formerly named Isle de Jonti by the early French explorers, from Chevalier de Jonti, an associate of the enterprising explorer La Salle, but now known as Amherst Island. Off the eastern extremity of this island there was formerly a small one, named Salmon Island. Judge Fairfield, who was brought up from childhood in this locality, tells me that when a boy, some fifty years ago, he was on it, and it was then, he supposes, over an acre in extent. Within the last twenty years I remember this island, having seen it in the distance from the bay and main shore opposite; and it was then conspicuous by a large elm tree growing upon it. Now Salmon Island has entirely disappeared, and a shoal, with four feet of water over it, alone marks its former site. North of this, and near the main shore of the Bay of Quinte, separated by narrow channels, are three small islands, side by side, and hence named the Brothers. These islands also are under a process of disintegration; and the western one has almost disappeared. On one of these a recluse formerly resided, and supported himself by fishing &c.; but he left the locality some time ago.

The cause of these changes is confessedly of a glacial character. These islands are low, and little above the level of the waters of Lake Ontario and the Bay of Quinte. They are so situated, in a range with the Lower Gap (the lower outlet of the bay to the lake), that the prevailing south or S.S.E. wind blows the drift-ice, which is apt to pile up on such spots, to a great height; and loading itself with a cargo of earthy material, gravel, stones or boulders, it acts upon such exposed spots and carries them away piecemeal. As an evidence of this disintegrating action, I may mention that last winter, on a low rocky limestone point about 4½ feet above the level of the water, in the range of the Lower Gap and on the opposite shore of the mainland, a large mass of drift ice was piled to such a height, on a spot between Perrot's Bay and Collins Bay, as to obstruct the high road that passed by it. This spring there were left on the point some large heavy boulders and other *débris*, which were not there previously, and which had evidently been brought by this glacial agency from the direction of the lake and the islands already named; and this may be deemed the chief cause of the disappearance of Salmon Island and the disintegration of the group of the Brothers. Further eastward, and opposite the village of Bath, tradition states that in the days of the early settlers, about A.D. 1786, there was a small island a short distance from the shore; and a shoal now marks the spot. Drift-ice from the direction of the Upper Gap may similarly have effected this.

Two or three typographical errors have crept into my former article as printed in No. 105, for November 1870, which I here correct. For "Barnhast's Island," &c., read "Barnhart's Island;" for "immature ice-bergs," read "miniature ice-bergs;" for *Saxicava vagosa*, read *rugosa*; and for "chalky sandstone," read "gritty limestone."

DISCUSSION.

Prof. RAMSAY mentioned that Sir William Logan had informed him that shore-ice in Canada, charged with boulders, had been known to produce grooves on the face of cliffs as well marked as those of glacial times. He had also mentioned the case of a boulder transported by ice which was of such a size as to have occasioned the wreck of a vessel which had struck upon it.

May 22, 1872.

John Arthur Phillips, Esq., of Cressington Park, Aigburth, Liverpool; George Fergie, Esq., Conduit Colliery, Brownhills, Walsall; and Arthur William Lawder, Esq., C.E., Almora, India, were elected Fellows of the Society.

The following communications were read:—

1. *A Communication from the* Right Hon. Earl Granville, *enclosing a Report from H.M. Minister at Rome relating to the recent* Eruption *of* Vesuvius.

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2. *On the* Phosphatic Nodules *of the* Cretaceous Rock *of* Cambridgeshire. By the Rev. O. Fisher, F.G.S.

(The publication of this paper is deferred.)

[Abstract.]

This paper contained an attempt to explain the origin of the phosphatic nodules which lie in a thin bed at the base of the Chalk in Cambridgeshire and are largely extracted, by washing the stratum, for the purpose of making superphosphate of lime. Two hundred and seventy tons per acre, at the rate of fifty shillings a ton, represents the valuable yield of the deposit, which is followed to the depth of about 18 feet. The nodules and other fossils of the bed are chiefly derivative, forming a concentrated accumulation from a deposit belonging to the Lower Cretaceous period. Some of the fossils, however, are believed to be indigenous to the deposit. *Plicatulæ* are attached to all the derivative fossils and nodules; and the sharp broken surfaces of the latter, with *Plicatulæ* on them, show that they were mineralized before they were deposited in their present *gisement*. The green grains of chlorite have been drifted into patches. Certain calcareous organisms are preserved; but many genera of mollusks only occur as casts in phosphate of lime. The deposition of the phosphatic matter has been determined by *animal* substances. There are two chief varieties of the "ordinary" nodules. The first are amorphous, or else finger-shaped; the second formed like a long cake rolled, partially or wholly, upon a stick. The surface of these two kinds of nodules is coriaceous and wrinkled; and they usually show marks of attachment to some foreign body. Certain species, clearly zoophytes, are converted into phosphatic

nodules; and when sections are made of these, they are found to show under the microscope structures and spicula allied to those of Alcyonaria. Slices of the *common* nodules show similar spicula, and occasionally reticular structure. When casts in plaster are made from *Alcyonium digitatum*, and coloured to resemble the nodules, the similarity in general form and structure of surface is very striking. The phosphate was probably segregated by the animal matter from its solution in water charged with carbonic acid, which is a known solvent of the phosphate; an analysis of the matrix has proved that phosphate of lime is appreciably present in it. The author doubted the derivation of the nodules from the denudation of the subjacent Gault, and exhibited a collection of these to show that they were distinguished by more stunted growth.

The deposit was on the whole considered to represent the thin band with similar fossils at the base of the Chloritic Marl, as seen in the west of England, in which district it is underlain by the true arenaceous Greensand. The absence of the true Greensand was attributed to the intervention of the old palæozoic axis of the London area; and it was finally suggested that a similar axis might stretch from Leicestershire to Harwich, causing the change in character of the Lower Cretaceous beds between Cambridgeshire and Norfolk.

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3. *Some Observations on the* Upper Greensand Formation *of* Cambridge. By W. Johnson Sollas, Esq., Scholar of St. John's College, Cambridge; Associate of the Royal School of Mines, London.

(Communicated by the Rev. T. G. Bonney, M.A., F.G.S.)

[Abridged.]

The so-called Upper Greensand formation around Cambridge consists of a Chalk-marl, with various inclusions disseminated throughout it. These inclusions are separated for manufacturing-purposes from the Chalk-marl by levigation, and sorted by a process of sifting into (i) larger bodies, which remain in the sieve, and (ii) smaller ones, which pass through it. The larger bodies consist almost entirely of the so-called "Coprolites;" and the smaller ones form the so-called "Greensand," which gives its name to the formation.

The Coprolites.—In all cases the coprolites are the result of the fossilization of organic matter or of the immediate products of its decomposition. The connexion between animal matter and the formation of coprolite is one of the most obvious facts of the whole subject. The bones of reptiles and fishes are incrusted with coprolite precisely on those parts where cartilage was most abundant. The palates of fish such as *Pycnodus* are not incrusted on their free surfaces; but their attached surfaces, once covered with cartilaginous tissue, are now quite imbedded in coprolite. In Crustacea such as *Palæocorystes* the under surface of the body, where animal matter could easily escape, is often one mass of coprolite; while the back of the carapace, which was not covered with animal matter, is generally free from incrustation. Many other examples might be cited, all pointing to the intimate connexion between the presence of animal matter and phosphatic deposition. The basis of animal matter was derived from various sources; the fossil remains of Vertebrata, Crustacea, Echinodermata, Mollusca, and so forth are coprolites the origin of which is clearly evident. But these constitute only a fraction of the whole; of the rest, the nature of which has hitherto been unknown, the majority are fossil Sponges, and of the minority remaining some few are formed from phosphatized animal matter decomposed so far as to have lost all traces of its original structure before mineralization. In some cases this animal matter may have been derived from small fish, since bones and scales of fish are found in some kinds of coprolites.

General similarity of some Coprolites to Sponge-forms.—Cylindroidal and cyathiform coprolites are abundant, consisting of a central core of Chalk-marl surrounded by an outer annular portion of coprolitic material, which is still impregnated with animal matter. These two parts together mark out the former existence of a hollow cylinder of animal matter, such as is exhibited in various recent and fossil sponges, and, taken in conjunction with other characters, seem to indicate an affinity to the Spongidæ. If this be so, the chalk core fills up what was once the cloaca of the sponge, and the phosphatic material replaces its animal matter. Minute pits upon the surface indicate the oscula. More important facts regarding this and other forms will form the subject of a future communication. In the Upper Chalk silicified sponges form flints, in the Upper Gault phosphatized sponges form coprolites; thus the coprolites might almost be termed the flints of the Gault.

The Greensand consists of (1) calcareous, (2) siliceous, (3) glauconite and coprolitic granules.

(1) *Calcareous grains* comprise sponge-spicules, spines and plates of Echinoderms, minute shells, shell-fragments and prisms, Polyzoa, bivalve Entomostraca, microscopic corals, Foraminifera, and calcareous concretions.

Calcareous concretions.—Rather abundant, subspherical granules varying in size, generally from $\frac{1}{15}$ to $\frac{1}{30}$ of an inch diameter, looking like rounded grains of milky-white quartz or spinose Foraminifera. Sections reveal a crystalline structure radiating from the centre, crossed by concentric lines of growth. Centre with a nucleus or not.

Foraminifera.—*Trochammina* and *Lituola* very abundant; *Lagena*, entosolenian and ectosolenian forms; *Nodosaria*, *Dentalina*; *Orthocerina*, very arenaceous forms; *Frondicularia*, *Vaginulina*, *Flabellina*, *Textularia*, and *Bulimina*, very arenaceous forms, of large size; *Cuneolina*, *Rotalia*, and *Globigerina*. Numerous species of *Lagena* occur abundantly, especially entosolenian forms: except *L. apiculata*, recorded by Reuss in the Gault, this genus has not hitherto been found below the Maestricht Chalk.

Entomostraca.—*Cythereïs quadrilatera*, *C. ciliata*, *C. triplicata*;

Bairdia subdeltoidea; *Cytherella truncata*; *Cythere punctatula*, *C. umbonata*, and others. *C. umbonata* has not been found before below the Chalk-marl.

(2) *Siliceous sand.*—Small grains of coloured quartz, obsidian, grit, and other rocks form a small proportion of the Greensand. Foraminifera of arenaceous habit often imbed these grains in their tests.

(3) *Glauconite and Phosphate Grains.*—The phosphate grains consist of coprolitic *débris*, coprolitic casts of Foraminifera, and small ovuloid granules and cylinders of unknown derivation.

The glauconite grains are the casts of Foraminifera, possibly also of other minute shells. The larger casts, about $\frac{1}{40}''$ to $\frac{1}{60}''$ in diameter and less, are marked into projecting lobes by deep sulcations, generally lined at the bottom with white calcareous matter, which serves to mark out the limits of each lobe. These forms are derived from *Textularia*, *Lituola*, and *Bulimina*; in size they correspond very closely with such a derivation, just passing through the meshes of a sieve which retain almost all the numerous *Buliminæ* mingled with them. Each lobation of the cast corresponds to the interior of a chamber of the Foraminifer; and each white calcareous line between the lobes is the edge of the septum which once separated adjoining chambers, and now, in some cases, extends inwards between their casts. This is shown by sections made in various directions through the green grains. When one of these sections of glauconite is viewed with polarized light, distinct colours are obtained; with parallel prisms, dark green; and a bright, lighter-coloured green, with crossed prisms. Sometimes *Buliminæ* are met with having part of their shell worn away, revealing a green cast within. Besides the above, other forms are found as casts in the sand—*Orthocerina*, numerous elongated triangular pyramids (rarely constricted into definite lobes), *Rotalia*, one or two minute *Nodosariæ*, small fusiform casts from *Lagena*, and distinct *Globigerina*-casts. Minute globules $\frac{1}{1000}''$ to $\frac{1}{200}''$ in diameter, occur plentifully the smaller ones are probably detached spheres from *Globigerina*-casts, and the larger ones casts of chambers broken off from other Foraminifera, as *Bulimina*; frequently glauconite may be seen through the worn-away shell of such chambers. *Globigerina*, *Rotalina*, and various pseud-arenaceous forms sometimes show green casts in their interior. From the resemblance of most of the green grains to the Foraminifera found with them, from their rough parallelism in size, from the appearance of many of the grains when sections are made of them, and from the occurrence of glauconite-casts in the interior of the original Foraminifera, we must attribute to the green grains a Foraminiferal origin. That this has not been determined by previous observers is partly due to the use of acid, after Ehrenberg's directions, in preparing the sand; this of course would obliterate the calcareous lines which distinguish the lobations. The silica and various silicates mingled with the glauconite grains must have thrown the analysis of these grains hopelessly wrong.

In conclusion, I have great pleasure in thanking the Rev. Mr. Bonney, of St. John's College, for the kindness he has shown me in many ways throughout this investigation.

Discussion.

Prof. Phillips was glad that his casual remark had produced such satisfactory results as the papers he had heard. It was satisfactory to find that the bulk of the phosphatic nodules exhibited such marked traces of an organic origin. Though he had to some extent been prepared for this, it appeared that the view might be extended much further than would at first sight have been anticipated. He drew an analogy between the preservation of the forms of sponges in their silicified fossils with that of the soft organic bodies in the Greensand by phosphatic matter. In each case the surrounding water contributed a large amount of either flint or phosphate of lime, which was segregated and accumulated round certain centres or nuclei of organic bodies.

Prof. Ramsay inquired from what sources the abundance of phosphatic matter requisite for the production of these fossils could have been derived. In such thin strata, which seemed to indicate a transition from a land to a marine surface, it was a matter of great difficulty to his mind to account for so great an abundance of phosphatic matter.

Mr. Godwin-Austen remarked that phosphoric acid was largely present in sea-water, and instanced the present seas, where, as on the Newfoundland banks, fish existed in enormous quantities, and no doubt also phosphatic matter. The Cambridge beds, though so rich, were by no means unique of their kind. He referred to a paper communicated some years ago to the Society by Mr. Payne, as affording many interesting particulars with regard to such beds. He considered that much of the phosphate attaching to decaying animal matter might have been derived from comminuted excrementitious deposits floating in the water.

The Rev. T. G. Bonney remembered a fact quoted by the late Dr. Mantell as to the large quantities of dead Mollusca which had been observed floating down some of the American rivers, and which had been regarded as a plentiful source of phosphatic matter. Small fishes might also have furnished a considerable quantity, and their value as manure was recognized at the present day. With regard to the nodules being Alcyonaria or sponges, he observed that what spicules he had seen appeared more like those of sponges. He agreed with Mr. Sollas as to the foraminiferal origin of many of the green grains. He did not agree with Mr. Fisher in attributing all the nodules to the bed in which they were found, but thought that a considerable portion might be referred to the upper part of the Gault. In proof of the washing the Gault near Cambridge had undergone, he mentioned the occurrence there of a number of boulders of rocks quite foreign to the district.

Mr. J. F. Walker thought that most of the fossils of the phosphatic band at the base of the Chalk-marl were derived from the Gault, whilst the bed differed from Chalk only by green grains becoming gradually more abundant. The fossils were generally much waterworn; the characteristic fossils of the Warminster Greensand were absent; and the most abundant fossils were all of Gault species. It seemed that wherever these accumulations of phosphatic matter occurred, denudation had taken place, and that they were the residuary heavy materials of a large thickness of rock. This might also be observed in the Upware and Potton beds.

Mr. Whitaker observed that the Upper Greensand thinned out as much to the south as to the north of London. He inquired as to the alleged abundance of phosphate of lime in the upper part of the Gault. He doubted whether the thin band at Cambridge could represent the great thickness of Upper Greensand which was to be found in some other districts. He regarded it rather as a gradual passage into chalk, though the line of demarcation was evident on the Gault. Though agreeing with Mr. Walker as to some of the fossils having been derived from the Gault, he could not regard them all as having come from that source.

Mr. Meyer thought that the Greensand had always been absent in the Cambridge district, and mentioned the occurrence of a bed of much the same character as that in question at Niton in the Isle of Wight.

Mr. Forbes pointed out that the amount of phosphatic matter in fishes was so small that it was difficult to assign such an abundance as that described to this source. In limestones all but entirely composed of shells, he could find only from $\frac{1}{2}$ to 1 per cent. of phosphate of lime. Even with true coprolites, he thought that they had become richer in phosphate since their deposition; but whence this phosphate was derived he would not pretend to say. He thought this question of derivation still open.

Prof. Morris mentioned the occurrence of similar deposits near Wissant, on the coast of France, and near Calne, in Wiltshire. He called attention to the extremely quiet nature of the sea in which the phosphatic bed had been deposited, and observed on the existence in recent times on certain sea-shores of ooze containing a large amount of phosphatic matter.

Mr. Fisher, in reply, stated that he had in his paper but slightly touched on the sources of derivation of the phosphate of lime; but as to the possibility of that substance being localized and derived in large quantity from fish, he pointed out that the principal manure of modern times, guano, was derived from this source. He alluded to the possibility of some process of dialysis having contributed to the segregation of the phosphate. He disputed the identity of the nodules in the Gault and in the chloritic marl of Cambridge. As to the character of the fossils, he regarded it as the same as that to be found in a thin band at the base of the Chalk in parts of Hants and Dorset.

Mr. Sollas had examined sections of the fossils from the Cambridge beds under the microscope, but had failed to find the canals or tuberculated spicules characteristic of Alcyonaria. He had, however, in the sand found numerous indisputable sponge-spicules. He had, moreover, found in sections of the coprolites spicules such as were regarded by Dr. Bowerbank as characteristic of sponges. He hoped, however, to recur to the subject. Both Mr. Fisher and himself concurred in removing these nodules from the category of concretions, and placing them under the head of organic fossils. The transported blocks in the beds bear evidence of glacial action, and, he considered, had been brought from Scotland or Scandinavia. The cold sea then existing at the base of the Scandinavian chain of mountains flowed southward over the bottom of the ocean, carrying with it mineral matter in solution, particularly phosphates; so that in this way, he thought, some portion of the phosphatic matter was derived from the decomposition of the volcanic rocks north of the Lammermuirs, which were rich in this substance, and of which rocks he had found fragments near Cambridge. He considered that, under certain circumstances, the phosphatic matter present in water would combine with animal matter, and hoped at some future time to offer some remarks on this subject to the Society.

June 5, 1872.

Isaac Shone, Esq., of Bersham Hall, near Wrexham, Denbighshire, was elected a Fellow, and Prof. J. D. Whitney, of Cambridge, U.S., a Foreign Correspondent of the Society.

The following communications were read:—

1. *Notes on* Sand-Pits, Mud-discharges, *and* Brine-Pits *met with during the* Yarkand Expedition *of* 1870. By George Henderson, M.D., F.L.S., Surgeon H.M. Bengal Medical Service, and lately Medical Officer to the Yarkand Expedition of 1870.

(Communicated by R. Etheridge, Esq.)

Whilst accompanying Mr. T. D. Forsyth to Yarkand in the summer of 1870, we came upon extensive tracts of ground indented with very remarkable circular pits, which I was very much puzzled to account for.

Where first seen, they appeared like the holes made in washing for gold, as practised both in Tibet and Yarkand; but there was none of the excavated material to be seen round their margins, and they were a hundred miles or more from any human habitation; besides, they were much too regular in size and shape to be thus accounted for.

I noted at the time every circumstance which I thought likely to give a clue to the manner of their formation; but, from the rapidity of our progress (15 to 30 miles a day), my notes were necessarily very imperfect. I have formed, however a theory regarding them, which Mr. Etheridge considers feasible; and he has asked me to give the result of my observations to the Geological Society.

After crossing the Karakoram watershed, at an altitude of 19,600 feet above the sea-level, we came to a plateau elevated about 18,000 feet above the sea, and which sloped very gently towards the plains of Central Asia, with the Kuen-Lun range, 20,000 to 24,000 feet high, intervening between us and these plains.

After two days' march (50 miles) we came to a number of limestone ridges, rising from 200 to 500 feet above the plain, with wide valleys between them; and in one of these valleys, between the camps named Luk Zoong and Tarl Dat, I first noticed the circular pits. The valley was about eight miles long, and from half a mile to a mile wide, and had a very gentle slope. The surface of the ground consisted of sand, clay, and gravel (formed mostly of angular fragments), in varying proportions, and for miles was indented with pits, all very regularly circular in shape; they varied in diameter from six to eight feet, and were from two to three feet deep. The sides sloped regularly towards the centre; and some of them were partially filled up with sand, which seemed to have been blown by the wind. The intervals between the pits were about equal to their diameters; and there were no raised ridges round their margins. The soil was quite dry; and there were no signs of water having flowed over it; nor was there any saline efflorescence.

At the head of the valley, and where side-valleys debouched, there were water-channels, which were in a few places moist. All the country round is as nearly as possible absolute desert. The little rain or snow which falls in these elevated and arid regions evidently finds its way under the surface of the ground in this particular valley.

At the end of the march, near Tarl Dat, lat. 35° 15′ N. and long. 79° 30′ E. (according to Hayward's map, published in the 'Journal of the Royal Geographical Society'), the ground sloped much more rapidly, and a series of springs issued from the soil and supplied a large ice-bed twelve to fifteen miles in diameter. Here the pits were again seen, but were less regular in size and few in number. Many of them had a mound of dry frothy mud projecting from them to a height of two or three feet. A very intelligent Sikh trader, who had repeatedly traversed this region, told me, in answer to my inquiries, that after rain these pits at Tarl Dat frothed like yeast.

After three marches (50 to 60 miles) we came to the Karakash river; and in the extensive marshes (half a mile to a mile across) which intervene between the river and the Kuen-Lun ranges to the north, we again saw the circular pits; but here they were partially filled with strong brine, and some were incrusted with common salt, which our followers collected for use with their food.

I find no mention made of these pits by Hayward, although he travelled over the same ground; but Mr. Shaw, in his book entitled

'High Tartary, Yarkand, and Kashgar,' p. 97, thus alludes to some he noticed in the Karakash valley:—

"Nov. 2 [1868]: Marched down the Karakash stream, which now flows freely between ice-borders. It is fed by numerous warm springs; hence its freedom from ice. But these springs give the whole water a brackish taste.

"A couple of miles from last night's camp we crossed a little plain dotted over with small craters, four or five yards across and two or three feet deep in the middle. The bottom of these craters is occupied by a deposit of common salt or saltpetre. The servants took a supply for common use."

Again, at p. 98:—

"Nov. 5: A succession of fine meadow-plains full of salt-craters, larger than the former ones (some six or seven yards across). Some were full of concentrated brine (unfrozen in most), which on evaporating will give the usual salt deposit, I suppose. In this valley, wherever there is grass there is also saline efflorescence in the soil. I fancy both depend on the presence of moisture, and hence occur together."

Mr. Shaw makes no mention of the pits near Tarl Dat.

My theory of the formation of these pits is as follows. I suppose that under the surface there is a layer of sand, and under the sand a stratum of clay; and that the water which sinks into the ground at the head of the valley flows in sand or gravel under the latter. In the Karakash valley, quicksands and quagmires are very common; and whilst exploring the pits there, my horse repeatedly sank up to the girths of the saddle. In the upper part of its course the Karakash river sometimes disappears for miles and flows under the surface of the ground. Where the pits are formed I assume the existence of a layer of clay which keeps the water down until it issues in a series of springs at Tarl Dat, where the ground slopes more rapidly. I suppose that the water, flowing in very varying quantity at different times, gradually eats away the clay in certain places, and allows the sand to escape, and circular patches of the surface subside and form the pits. Depressions formed in this way are very common in the Punjab, particularly about Umballa and between Jhelum and Rawil Pindi. Sometimes at Umballa many square yards of ground thus subside and leave an enormous hole twenty or more feet in depth, with vertical sides. This process has gone on to such an extent in some localities between Jhelum and Pindi that more than half the surface-area has been lowered thirty or forty feet, and the whole country has been cut up into ravines with nearly perpendicular sides. I account for the mud-discharges at Tarl Dat by supposing that after a fall of rain or snow the air contained in the water-bearing stratum would get churned up with the water and mud, and be ejected as frothy mud at Tarl Dat. I believe the brine- and salt-pits in the Karakash valley are formed in the same way. This river rises and falls several feet every day; at some seasons it is almost dry, at others it overflows its banks. It is fed entirely by melting snow from the mountains, and by a few hot or warm springs along its banks. In August 1870 it was fordable with difficulty, except about 9 A.M., when it is usually at its lowest. I suppose that the rise and fall of the river alternately fills and empties the bottoms of the pits, and the water left in these pits gradually gets concentrated by evaporation. I am not aware how much salt the water contains; but there is saline efflorescence all along its banks, and the prevalence of tamarisks shows that the water or soil, or both, contain salt. It is difficult to account for the extreme regularity in the shape and size of the pits. Mr. Shaw gives four to seven yards as the diameter of those he noticed; those seen by me were not above four to seven feet as a rule. Possibly we have both observed correctly; and in some localities they may be large, and in others small. Mr. Etheridge has suggested to me that these pits may be analogous to the sand-pipes and swallow-holes in the Chalk noticed in the 'Memoirs of the Geological Survey of Middlesex,' pp. 11 and 12, or more probably to some natural pits on the heaths of Dorsetshire, described by the Rev. Osmond Fisher in this Journal, vol. xv. p. 187; but on these points I feel I am not competent to give an opinion.

Discussion.

Mr. Prestwich pointed out that the pits seemed due to quite another cause than the pipes in the Chalk and other calcareous rocks, as they did not appear to arise from erosion by carbonic acid.

Mr. Thorp suggested an analogy between the phenomena in Yarkand and those at Nantwich, and thought that the pits might be due to solution of rock-salt below the surface.

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2. *On the* Cervidæ *of the* Forest-bed *of* Norfolk *and* Suffolk.

By W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S.

Contents.

1. A New Species.

Among the very remarkable and little-known *Cervidæ* from the Forest-bed of Norfolk, there is one form which is certainly new to Britain, and which I cannot identify with any of the Continental species. It is represented by a series of antlers in the Museums of Norwich and of the Geological Survey of England and Wales, in the British Museum, and in the collection of Mr. Jarvis, of Cromer. The clue to the restoration of the perfect antler is afforded by a specimen which was obtained by my friend the late Rev. S. W. King from Happisburgh.

The series of antlers in question is characterized by the sudden downward curvature of the cylindrical brow-tyne; and I have therefore named the animal to which they belonged *Cervus verticornis*.

Characters.—The base of the antler is set on to the head very obliquely (fig. 1); and immediately above it there springs the cylindrical brow-tyne, *b*, which in this specimen (fig. 1) has been torn away from the antler before it was deposited in the ferruginous gravel. Its sudden downward and outward curvature is shown in the magnificent antler found by the Rev. J. Gunn, and now in the Norwich Museum (fig. 2), and which has been described by Dr. Falconer*. Immediately above the brow-tyne the beam is more or less cylindrical; but it becomes gradually more and more flattened until it gives off the oval second tyne, *c*; and it does not again recover its rounded section. A third, flattened tyne (fig. 1, *d*) springs on the anterior side of the antler; and immediately above it the broad expanded crown is proved, by the convergence of the compact outer walls of the antler at *e*, to have terminated in at least two points, and possibly more. No tyne is thrown off on the posterior side of the antler; but the sweep is uninterrupted from the antler-base to the first point of the crown. The beam is slightly flattened at the front where the brow-tyne, *b*, is given off. In all the specimens which have not been rolled, the surface is traversed by broad and shallow grooves. The second tyne, *c*, is, in all the specimens, set on in a different plane from the brow-tyne.

A secondary brow-tyne is given off close to the base in one large antler in the British Museum. This circumstance, however, is of no more importance in classification than in the parallel case of the Stag. In Mr. Gunn's large specimen in the Norwich Museum a small point or "offer" immediately below the brow-tyne may indicate that, on the older antlers, the development of two brow-tynes was not uncommon.

These antlers differ from those of the *Cervus megaceros* in the greater curvature downwards of the brow-tyne and the close approximation of the second tyne, *c*, to *b*, as well as in the crown being less palmated. The beam also is stouter in proportion to its length.

* "The specimen is of left side, and consists of the basal portion of a huge horn that had been shed. The brow-antler is given off about 2 inches above the bur, and is curved abruptly downwards and outwards like a huge hook; it is perfectly terete, and the portion remaining shows no appearance of subdivision. It is very boldly channelled on the convex outer side, smooth inwards. The beam above the bur is not quite terete, but oval, with a ridge behind, opposite the brow-antler. The beam then contracts, and becomes nearly cylindrical, and then expands, giving off from the anterior outer side a large antler at about 6–7 inches above the bur, and $4\frac{1}{4}$ inches (lower edge) above upper side of brow-antler. The beam is then somewhat flattened in a direction corresponding with that of the brow-antler. Only the section of the base of the median antler seen. A ridge descends from lower edge of median antler, outer side, to the ridge or tuberosity opposite the brow-antler.

"The brow-antler is given off much higher than I have ever seen it in the Irish Elk; the beam less cylindrical than in the latter, and more erect, without the elegant, long, reclinate reach in the latter. The low offset of the median antler is also very different. It appears to indicate a huge Deer, as large as the Irish Elk, but quite distinct."—*Palæontographical Memoirs*, vol. ii. p. 479.

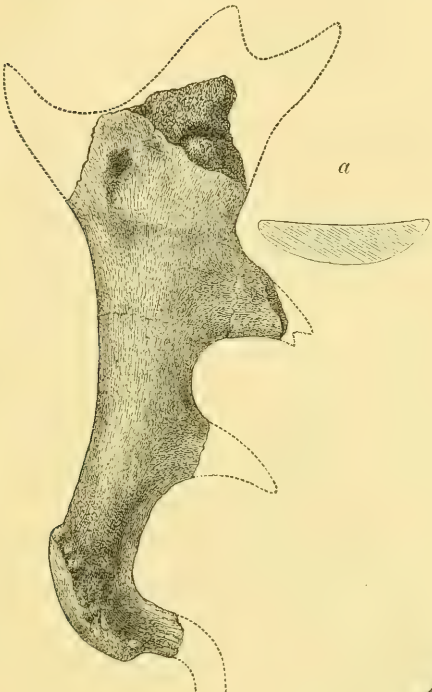

Fig. 1.—*Right Antler of* CERVUS VERTICORNIS (Jermyn-Street Museum, King collection).

a. Section across palm.

Fig. 2.—*Left Antler of* CERVUS VERTICORNIS (Norwich Museum, Gunn collection).

There is, however, a general resemblance between the two animals; and the fully grown *Cervus verticornis* must have rivalled the Irish Elk in size, although its antlers were not so wide in their sweep, or so elegant in their outlines.

The following are the measurements (in inches) of the principal antlers which I have examined:—

	Geolog. Survey (King collect.).	Norwich Museum.	Norwich Museum. (Gunn collect.).	British Museum.
Maximum length	12·0	......	13·5	17·5
Circumference of beam	4·8		......	19·0
Basal circumference	7·5	7·2	10·4	11·5
Long diameter of base	3·0			
Short diameter of base	2·0			
Circumference of brow-tyne	2·5	......	7·5	8·0
From brow-tyne to second tyne	2·0	......	3·3	6·5
From second tyne to third tyne	1·8	2·8		

2. Other Species from the Forest-bed.

The *Cervidæ* of the Forest-bed present a most remarkable mixture of forms. Dr. Falconer has determined one species, *Cervus Polignacus* (Palæontographical Memoirs, ii. p. 479), which occurs also in the Pliocene lacustrine deposit of Mont Perrier, near Issoire; and he has described a new species, with peculiar flattened branching antlers, as *C. Sedgwickii* (*op. cit.* p. 476). The Stag, Roe, and *Cervus megaceros* are also present. To these I am now able to add the species which M. Laugel obtained from the Pliocenes of St.-Prest, near Chartres, and described in the 'Bull. de la Société Géol.' 2d ser. xix. p. 711, 1862, under the name of *Cervus* (*megaceros*) *carnutorum*.

It is based on the frontlet with portions of the beams of the antlers. The latter are round and deeply grooved, and the burr is strongly defined and annular. The brow-antler is removed nearly 2 inches from the burr, and rises at an acute angle to the beam. According to Prof. Gervais, the skull differs from that of the Irish Elk in the interval between the bases of the antlers being smaller. The following measurements are taken from his work 'Animaux Vertébrés vivants et fossiles,' 1867–9, p. 85:—

	St.-Prest.	Oyster-beds, Norfolk.
Interval between pedicles	1·75	1·8
Frontal measurement from below pedicle	5·92	6·0
Suborbital foramen to its fellow	3·6	3·7
Circumference of beam at burr	10·2	7·3
Distance from burr to first tyne	1·85	
Length of pedicle, measured behind	......	1·9

A waterworn frontlet of *Cervus* in the Museum of the Geological Society, and obtained from the "Oyster-beds" of the Norfolk coast agrees in every measurement with the above, with the sole exception that the antler is slightly smaller (a point which varies with age). Although, therefore, the brow-tyne has been broken away, which is so important a guide to the determination of the different Cervine species, the specimen from Norfolk may be assigned to the same species. It is so like the lithograph given by Prof. Gervais (*op. cit.* pl. xvi. fig. 4) that it does not require a figure. A second frontlet of precisely the same character has been obtained from the Forest-bed at Easton, Suffolk, by Mr. Ewen, and is now preserved in the Chichester Museum. The left antler is in the same condition as that of the French specimen, being broken off just above the first tyne. The base of a shed right antler obtained from the Chillesford beds of Aldeby by the late C. B. Rose, Esq., of Yarmouth, and now in the Norwich Museum, presents the deeply channelled cylindrical beam with a strongly defined burr running round it at right angles to the long axis, the brow-antler rising at a distance of about 2 inches from the burr—points which characterize *C. carnutorum*. In my belief it belongs to that species. The basal circumference is 6·5; and the first tyne is 2·5 inches from the burr (fig. 3). Nor is there

Fig. 3.—*Right Antler of* Cervus carnutorum (Norwich Museum, Rose collection).

any thing strange in the Deer of St.-Prest being found in the Forest-bed, since *Trogontherium Cuvieri, Rhinoceros megarhinus,* and *Hippopotamus major* have been furnished by both strata.

3. Classificatory Value of the Cervidæ.

It remains now to examine the value in classification of this singular group of Cervidæ, consisting of, at the very least, the following species:—

Cervus elaphus.	Cervus carnutorum.
—— megaceros.	—— Sedgwickii.
—— capreolus.	—— verticornis.
—— Polignacus.	

The first three of these are not of Pliocene age, if the Mammaliferous strata of Auvergne, Marseilles, and the Val d'Arno be taken as the Pliocene standards. Their presence, therefore, in the Forest-bed points forwards rather than backwards in time, since they are abundant in the caves and river-deposits of the Pleistocene age. The next, on the other hand, is a well-known Pliocene species; while the *Cervus carnutorum* is common to the Forest-bed and the river-strata of St.-Prest, and the last two peculiar to the Forest-bed.

This peculiar mixture of Cervine species seems here to indicate that, in classification, the Forest-bed belongs rather to an early stage of the Pleistocene than to the Pliocene; and this inference is corroborated by the presence of the Mammoth, which is so characteristic of the Pleistocene age.

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3. *The* Classification *of the* Pleistocene strata *of* Britain *and the* Continent *by means of the* Mammalia. By W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S.

Contents.

1. The Principle of Classification.

The Pleistocene period was one of very long duration, and embraced changes of great magnitude in the geography of Europe. The climate, which in the preceding Pliocene age, in Northern and Middle Europe, had been temperate, at the beginning of the Pleistocene gradually passed into the extreme arctic severity of the glacial period; and this change caused a corresponding change of the forms of animal life, the Pliocene species (whose constitutions were adjusted to temperate or hot climates) yielding place to those which were better adapted to the new conditions; and since, as we shall presently see, there is reason for the belief that it was not continuous in one direction, but that there were pauses, or even reversions towards the old temperate state, it follows that the two groups of animals would at times overlap, and their remains be intermingled with each other. The frontiers also of each of the geographical provinces must necessarily have varied with the season; and the competition for the same feeding-grounds, between the invading and the retreating forms, must have been long, fluctuating, and severe. The passage, therefore, from the Pliocene to the Pleistocene fauna must have been extremely gradual in each area; and the lines of definition between the two must be, to a great extent, arbitrary, instead of being sufficiently strongly marked to constitute a barrier between the Tertiary and Posttertiary groups of life of Lyell, or between the Tertiary and Quaternary of the French geologists. The principle of classification which I shall adopt is that offered by the gradual lowering of the temperature, which has left its marks in the advent of animals before unknown in Europe; and I shall divide the Pleistocene deposits into three groups:—

1st. That in which the Pleistocene immigrants had begun to disturb the Pliocene mammalia, but had not yet supplanted the more southern animals. No arctic mammalia had as yet arrived. To this belongs the Forest-bed of Norfolk and Suffolk, and the deposit at St.-Prest, near Chartres.

2nd. That in which the characteristic Pliocene Cervidæ had disappeared. The even-toed Ruminants are principally represented by the Stag, the Irish Elk, the Roe, Bison, and Urus. *Elephas meridionalis* and *Rhinoceros etruscus* had retreated to the south. To this group belong the Brick-earths of the lower valley of the Thames, the river-deposit at Clacton, the Cave of Baume, in the Jura, and a river-deposit in Auvergne.

3rd. The third division is that in which the true arctic mammalia were among the chief inhabitants of the region; and to it belong most of the ossiferous caves and river-deposits in Middle and Northern Europe.

These three do not correspond with the Preglacial, Glacial, and Postglacial divisions of the Pleistocene strata in Central and North Britain, since there is reason to believe that all the animals which occupied Britain after the maximum cold had passed away, had arrived here in their southern advance before that maximum cold had been reached, or, in other words, were both Pre- and Post-glacial.

I shall first of all examine how this classification applies to Great Britain.

2. The Late Pleistocene Mammalia from British River-deposits.

The third or late division of the Pleistocene strata will be taken first. The evidence that it is far older than any of the Prehistoric*

* For definition of the term Prehistoric, see Introd. Brit. Pleistocene Mammalia, Palæont. Soc. 1866; "Prehistoric Mammalia of Great Britain," Congress of Prehistoric Archæology, Norwich, 1868, p. 269.

strata is clear and decisive. In many cases, as at Walton, in Essex, and Fisherton, near Salisbury, the former underlie the latter, and must therefore be older.

In other cases they form part of the basin in which the Prehistoric deposits lie, as in the case of the gravel-beds of Windsor or of London, and must therefore, from their position, be of higher antiquity than the latter. Nearly every valley in Great Britain (the glacier-areas, to which I shall return presently, being excepted) contains beds of brick-earth or of gravel, which were formed, as Mr. Prestwich * has clearly shown, before the valleys were cut by the streams to their present depths; and the difference between the levels of these old river-terraces has been shown by that eminent observer to be a rough measure of their relative antiquity, the highest being the oldest. The Prehistoric deposits, on the other hand, occupy for the most part the bottom of the valleys, and are seldom raised much above the level of the present stream. There is also a marked difference between the two in the materials of which they are composed. The Prehistoric as well as the present alluvia are for the most part formed of clays, more or less stiff; and the gravels are composed of pebbles more or less evenly sorted; and both were formed under conditions of climate not very different from the present. The Pleistocene brick-earths, on the other hand, very seldom consist of stiff clays; and the gravels contain large and small pebbles and angular blocks confusedly mixed together, which indicate that the conditions under which they were formed were different from those which are now presented by the temperate region of Europe. But the difference offered by the fauna which they present is, perhaps, the most striking.

It will be unnecessary to give the river-deposits in Great Britain which have furnished the remains of the following animals, since they have already been published in the Quarterly Journal of the Geological Society, vol. xxv. pp. 192 *et seqq.*

It would, of course, be unreasonable to expect that the remains of all the animals inhabiting the country at the time would be present in one small river-deposit, and still more improbable that they would all be discovered in the small area which happens to be open for examination. By correlating, however, the animals from many localities, a fair estimate can be obtained of the whole fauna. The greater liability of one animal to drowning than another must be taken into consideration. For this reason the Otter, probably from its aquatic habits, is extremely rare, while the Squirrel, living in trees, would run little risk of a watery grave, and has only been found in one Pleistocene deposit in Great Britain. Altogether the following twenty-eight species of animals have left their remains to prove that they existed on the surface of the Pleistocene continent that was drained by the rivers in the deposits of which their remains have been found.

* Philosophical Transactions, vol. cliv.

Homo, *L.* Man.
Ursus arctos, *L.* Brown Bear.
—— ferox, *Lewis & Clark.* Grizzly Bear.
Mustela erminea, *L.* Ermine.
Lutra vulgaris, *L.* Otter.
Canis vulpes, *L.* Fox.
—— lupus, *L.* Wolf.
Hyæna crocuta, *Zim.*, var. spelæa, *Goldf.* Cave-hyæna.
Felis leo (spelæa), *L.* Cave-lion.
Cervus megaceros, *Hart.* Irish Elk.
—— Browni, *Dawk.* Extinct Fallow-deer.
—— tarandus, *L.* Reindeer.
—— capreolus, *L.* Roedeer.
—— elaphus, *L.* Stag.
Ovibos moschatus, *Blainv.* Musk-sheep.
Bos primigenius, *Boj.* Urus.
Bison priscus, *Owen.* Bison.
Hippopotamus major, *Desm.* Large Hippopotamus.
Sus scrofa (ferus), *L.* Wild Boar.
Equus caballus, *L.* Horse.
Rhinoceros hemitœchus, *Falc.* Slender Rhinoceros.
—— tichorhinus, *Cuv.* Woolly Rhinoceros.
Elephas antiquus, *Falc.* Narrow-toothed Elephant.
—— primigenius, *Blum.* Mammoth.
Lemmus (? grœnlandicus). Lemming.
Spermophilus (? superciliosus). Pouched Marmot.
Lepus timidus, *L.* Hare.
Mus musculus, *L.* Mouse.

The mammalia of Acton Green, obtained by Col. Lane Fox, and named by Prof. Busk, F.R.S., all probably belong to the late Pleistocene division; for although the peculiar flat-antlered deer, *C. Browni*, and the Hippopotamus are found side by side, they are associated with the Mammoth and the Reindeer.

3. The late Pleistocene Ossiferous Caves of Britain.

It remains now to compare this fauna with that of the Ossiferous caves. In comparing the Table of the distribution of the Mammalia in Britain, which I have published in the Q. J. G. S. (vol. xxv.) with the above list, it will be seen that all the mammalia which are found in the latter, with the exception of *Ovibos moschatus*, occur also in the former. Those animals which are peculiar to the caves consist chiefly of the carnivores, the Cave-bear, Glutton, Leopard, Lynx, and Wild Cat, which would naturally haunt such places. The larger number of rodents obtained from the caves is due to the admirable way in which Mr. Ayshford Sanford has worked out the Mendip fauna, and is not the result of their absence from the river-beds; the same amount of care bestowed on the latter would probably equalize the numbers. It is therefore evident that the cave-fauna is identical with that of the river-strata, and that, consequently, both must be referred to the same point of geological time—to a time when this group of animals lived in the caves and valleys of the Pleistocene continent. This was the conclusion to which Dr. Falconer was led by the examination of the caves of Gower, and it has been amply proved by every subsequent discovery.

The late Pleistocene corresponds in part with the Reindeer-period of M. Lartet; but it comprehends also his three other periods; for the Spotted Hyæna, the Lion, the Cave-bear, the Mammoth, the Woolly Rhinoceros, the Bison, and the Urus are so associated together with the Reindeer in the caves and river-deposits of Great Britain, that they do not afford a means of classification. The arctic division of the Mammalia was then in full possession of the area north of the Alps and Pyrenees. It also corresponds with the Post-glacial period, as I have used the term, and covers the vast lapse of time, extending from the beginning of the era of intense cold down to the enormous break which separates the Pleistocene from the Prehistoric division of the Tertiary period.

4. Magnitude of the Interval between the Late Pleistocene and the Prehistoric Ages in Britain.

The magnitude of the break in time between the Late Pleistocene and Prehistoric ages may be gathered not merely from the physical evidence, but also from the disappearance from Britain, in the interval, of the following species, of which the last five, and possibly the last seven, have become extinct.

Glutton.	Bison.	Cave-Bear.
Spotted Hyæna.	Hippopotamus.	Rhinoceros hemitœchus.
Panther.	Lemming.	—— tichorhinus.
Lion.	Hamster.	Elephas antiquus.
Lynx.	Tailless Hare.	—— primigenius.
Musk-sheep.	Lepus diluvianus.	
Urus.	Arvicola Gulielmi.	

All these animals were eliminated out of the fauna before the Prehistoric deposits were accumulated; and the remainder lived on through the Prehistoric down into the Historic period.

5. The Middle Division of the Pleistocene Mammalia.

The middle division of the Pleistocene mammalia must now be examined, or that from which the characteristic Pliocene Cervidæ had vanished and were replaced by the invading forms from the temperate zones of Northern Asia. It is represented in Britain by the mammalia obtained from the Lower Brick-earths of the Thames-valley, at Crayford, Erith, Ilford, and Gray's Thurrock, by those from the deposit at Clacton, and most probably by those from the older deposit in Kent's Hole, and by the *Rhinoceros megarhinus* of Oreston. They consist of

Homo.	Cervus Browni.
Felis leo (spelæa), *Goldf.*	—— capreolus, *Linn.*
—— catus, *Linn.*	Ovibos moschatus.
Hyæna crocuta, var. spelæa.	Elephas antiquus, *Falc.*
Ursus ferox, *Lew. & Clark.*	—— primigenius, *Blum.*
—— arctos, *Linn.*	Equus caballus, *Owen.*
Canis lupus, *Linn.*	Rhinoceros tichorhinus, *Cuv.*
—— vulpes, *Linn.*	—— hemitœchus, *Falc.*
Lutra vulgaris, *Erxl.*	—— megarhinus, *Christ.*
Bos primigenius, *Boj.*	Sus scrofa, *Linn.*
Bison priscus, *Owen.*	Hippopotamus major, *Desm.*
Cervus megaceros, *Hart.*	Castor fiber, *Linn.*
—— elaphus, *Linn.*	Arvicola amphibia, *Desm.*

The discovery, by the Rev. O. Fisher, of a flint-flake in the undisturbed Lower Brick-earths of Crayford, in the presence of the writer, in April 1872, proves that man was living at the time of the accumulation of these fluviatile strata.

If the mammalia from these deposits be compared with the Preglacial or Pliocene on the one hand, and with the Late Pleistocene on the other, it will be seen that they are linked to the former by the *Rhinoceros megarhinus*, and to the latter by the *Ovibos moschatus*. The absence of the Reindeer, which was so numerous in the valley of the lower Thames, and the abundant remains of the Stag, seem to me to point backwards rather than forwards in time, and to imply that the Lower Brick-earths are not of Late Pleistocene age, just as the absence of the characteristic Early Pleistocene species shows that they are not of that age. The evidence seems to me sufficient to establish a stage intermediate between the two. Nevertheless the evidence is sufficiently conflicting to cause Dr. Falconer to come to the conclusion that these strata are of Pliocene date, and Mr. Prestwich to believe that they belong to a late stage in the Pleistocene*.

The same group of animals, with the exception of the Megarhine and Tichorhine Rhinoceros and the Musk-sheep, is furnished by the fluviatile deposit at Clacton, in Essex, in association with the peculiar form of Fallow Deer which I have described under the name of *Cervus Browni*.

One of the most remarkable facts brought to light by Mr. McEnery is the former presence of the sabre-toothed Felis (*Machærodus latidens*) in the cave of Kent's Hole. Its characteristic canines are found associated with thousands of the teeth of Horse and Hyæna. Kent's Hole is the only place where this fell carnivore has been found along with the remains of Mammoth, Reindeer, and other Pleistocene mammals. It belongs to an archaic type, which sprang into existence during the Miocene times in France, Germany, and Switzerland, and preyed upon the Hipparion and Antelope in the plains of Marathon and on the Indian flanks of the Himalayas—to a type that coexisted with *Elephas meridionalis* and the Mastodon during Pliocene times in France, Germany, Britain, and Italy, and in South America preyed upon the gigantic Sloths and Horses whose remains are found in the Brazilian caves.

The large masses of breccia which occur in the cave-earth of Kent's Hole are remarkable for their hard crystalline structure, and prove that there was a stalagmite floor in the cave before the introduction of the earth, and long before the formation of the present stalagmite pavement. In a portion of the cave called the "gallery" there is evidence of the undisturbed part of this ancient stalagmite in a "ceiling, or uppermost floor," that extends from wall to wall, "without further support than that furnished by its own cohesion. Above it there is in the limestone-rock a considerable alcove. This branch of the cavern, therefore, is divided into three stories, or flats,—that below the floor occupied with cave-earth, that between the floor and ceiling entirely unoccupied, and that above the ceiling also without a deposit of any kind." From its being stained with cave-earth, as well as from its position, the ceiling, at the time of its deposition, must have been supported by cave-earth. It would, indeed, be as impossible for a solid horizontal sheet of stalagmite to be formed in mid

* Falconer, Palæont. Mem.; Prestwich, Geol. Mag.

air as it would be for a sheet of ice to be formed without resting on water. From some cause or other this ancient stalagmite has been in part broken up, and the materials by which it was formerly supported have disappeared. That, however, even prior to its formation animals dwelt in the cave is proved by the bones which are imbedded in the large fallen masses. Moreover there is reason to believe that certain fragments of bone and splinters of teeth, remarkable for their mineralization, that have been found in the earth now occupying the cavern, were derived from this more ancient deposit; for they differ essentially from the remains with which they are now associated, being heavier and of a more crystalline structure. Some splinters have assumed the fracture of greensand chert. So hard indeed was one of the canines of Bear, that it has been splintered by the hand of man into the form of a flint-flake, and has evidently been used for a cutting-purpose. Its fracture proves that it was mineralized before it was splintered; and as it was found in the present cave-earth, it must have been fashioned while the cave was being inhabited by palæolithic man prior to the accumulation of the earth. For these reasons the evidence in favour of these denser remains having belonged to the deposit which once supported the ancient floor seems to me to be incontrovertible.

This view opens up an entirely new field for investigation as to the discovery of the *Machærodus*; for it is very likely that this mammal may really belong to the older cave-earth, and not to the more modern, in which the remains of the Mammoth, Woolly Rhinoceros, and the like occur. But whether this be true or not, it adds a tenfold interest to the exploration of the cave, because there may be still left, in some nook or corner, masses of the older breccia, containing forms of life that had passed away before the arctic mammalia occupied the south of England.

The presence in the cave at Oreston*, in the same district, of the Pliocene *Rhinoceros megarhinus* (an animal which has never yet been met with in any of the Late Pleistocene caves or river-deposits) strengthens the conclusion that some of the caves in the south of England may contain a fauna that was living before the Late Pleistocene age.

Both these caves were probably occupied by the wild beasts for a very considerable length of time; and the remains left behind after each occupation would be extremely likely to be mixed up together, by the passage of water through the chambers, during the oscillations of level which undoubtedly took place during the Pleistocene age. Proof of such oscillations in the south of England is afforded by the submerged forest-bed of Bracklesham, in Sussex, which is covered over by a deposit of Boulder-clay and ancient marine shingle. This explanation of their presence seems to me to be more probable than the assumption that they were living during the later Pleistocene period in that area; for in that case their remains would be more commonly met with in the many caves of the south of England, as well as in those of the Late Pleistocene age in

* Quart. Journ. Geol. Soc. vol. xxvi. p. 457.

the South of France, where the proximity of the Mediterranean must have caused the temperature to be higher than in the north of France and Britain.

The evidence that Kent's Hole and Brixham Cavern had, at one time, been occupied by an accumulation of cave-earth and stones, which were sealed down with a coating of stalagmite, and that this was subsequently destroyed before either was filled with the deposits which it now contains, is clear and decisive.

During the Middle Pleistocene in the Thames valley, and at Clacton, the Woolly Rhinoceros, Elephant and Mammoth, competed for the same feeding-grounds with *Rhinoceros hemitœchus*, *R. megarhinus*, Hippopotamus, and *Elephas antiquus*. Although all the characteristic Pliocene Cervidæ had retreated, the Reindeer had not yet invaded that area: it was occupied by the Stag, the Roe, the Irish Elk, and *Cervus Browni*. The whole assemblage of animals, the Musk-sheep being excepted, implies that the climate was, at this time, less severe than when the Reindeer spread over the same area in the Late Pleistocene times, and was far more numerous than the Stag. It may, indeed, be objected that the classificatory value of the Musk-sheep is quite as great as that of *Rhinoceros megarhinus*; but in the case of the lower Brick-earths, the evidence of the latter as to climate agrees with that of the whole assemblage of animals, while that of the former is altogether discordant.

6. The Early Pleistocene Mammalia.

The fossil mammalia must now be examined which inhabited Great Britain during the Early Pleistocene period, and before the maximum severity of glacial cold had as yet been reached. The fossil bones from the forest-bed which underlies the Boulder-clay on the shores of Norfolk and Suffolk, have for many years attracted the attention of naturalists and geologists. The magnificent collections of the Rev. John Gunn and the late Rev. S. W. King gave Dr. Falconer the means of proving that the fauna of that ancient submerged forest differed from that of any geological period which we have hitherto discussed. And the careful diagnosis of all the fossils from this horizon which I have been able to meet with, shows that it was of a very peculiar character, being closely allied to the Pliocene of the south of France and of Italy, and yet possessing species which are undoubtedly Pleistocene. The following list is necessarily very imperfect, since the fragmentary nature of the fossils renders a specific identification very hazardous; and it only includes those which I have been able to identify with any degree of certainty.

Sorex moschatus.	Machærodus.	Hippopotamus major.
—— vulgaris.	Cervus megaceros.	Sus scrofa.
Talpa europæa.	—— capreolus.	Equus caballus.
Trogontherium Cuvieri.	—— elaphus.	Rhinoceros etruscus.
Castor fiber.	—— Polignacus.	—— megarhinus.
Ursus spelæus.	—— carnutorum.	Elephas meridionalis.
—— arvernensis.	—— verticornis.	—— antiquus.
Canis lupus.	—— Sedgwickii.	—— primigenius.
—— vulpes.	Bos primigenius.	

From the examination of this list, the peculiar mixture of Pliocene and Pleistocene species is evident. The *Ursus arvernensis, Cervus Polignacus, Hippopotamus major, Rhinoceros etruscus,* and *R. megarhinus,* the Horse, *Elephas meridionalis,* and *E. antiquus* were living in the Pliocene age in France and Italy, and probably in Norfolk. The Cave-bear, the Wolf, Fox, Mole, Beaver, Irish Elk, Roe, Stag, Urus and Wild Boar, and the Mammoth have not as yet been discovered in the Continental Pliocenes, as judged by the standards offered by the Val d'Arno and Southern France, and are more or less abundant in the late Pleistocene age. This singular association seems to me to imply that the Forest-bed fauna is intermediate between the two and, from the fact that only three out of the whole series, viz. *Ursus arvernensis, Rhinoceros etruscus,* and *Cervus Polignacus,* are peculiar to the Continental Pliocene, that it is more closely allied to the Pleistocene than to the Pliocene.

It is also very probable that this early Pleistocene age was of considerable duration; for in it we find at least two forms (and the number will probably be very largely increased) which are unknown in Continental Europe, although Pliocene and Pleistocene strata have been diligently examined in France and Germany. The very presence of the *Cervus Sedgwickii* and *C. verticornis* implies that the lapse of time was sufficiently great to allow of the evolution of forms of animal life hitherto unknown, and which disappeared before the middle and late Pleistocene stages. The *Trogontherium* also, as well as the *Cervus carnutorum,* both of which occur in the forest-bed and in the gravel-beds of St.-Prest, near Chartres, and which are peculiar to this horizon, point to the same conclusion.

The Cervidæ of the forest-bed, in this list, do not represent approximately the number of species: there are at least five, and perhaps six, represented by a series of antlers, which I do not venture to quote, because I have not been able to compare them with those of the Pliocenes of the Val d'Arno, of Marseilles, or of Auvergne.

Dr. Falconer pointed out that one of the peculiar characters of the fauna of the forest-bed is the presence of the Mammoth; and the evidence on which he considered the animal to be of Preglacial age in Europe has been fully verified by the molars from Bacton, which are now in the Manchester Museum. They were associated with *Elephas meridionalis* and *E. antiquus,* and are incrusted with precisely the same matrix as the teeth and bones of those species.

7. M. Lartet's Classification.

Before we proceed to the examination of the Pleistocene Mammalia of the Continent it will be necessary to ascertain the value of the received classification.

The late M. Lartet proposed in 1861 (Ann. des Sciences Nat. Zool. 1861, p. 217) the following chronological divisions of the Quaternary or Palæolithic age, or that which corresponds with the late Pleistocene. Acting on the *à priori* consideration that all the animals found in the caves and river-deposits of France did not invade Europe at one time, but successively, he has attempted to give the true sequence of the invasion, and assigns all the French caves and river-deposits to "l'âge du grand ours des cavernes, l'âge de l'éléphant et du rhinocéros, l'âge du renne, et l'age de l'aurochs." It seems to me that there are several fatal objections to this very generally received classification. It is necessary, in the first place, to show which of these animals came here first, before we can say that the age of the Cave-bear preceded that of the Mammoth, or the age of the Mammoth that of the Reindeer, or lastly, the age of the Reindeer that of the Aurochs. We must know for certain that this was the true order of their advent; and of this M. Lartet has not advanced any satisfactory proof. It is certainly true that the Mammoth was in occupation of the Thames valley and of the area which is now covered by the German Ocean before the Reindeer had arrived. That this must necessarily have been the case follows from the fact that the former is a less arctic animal than the latter—being found in the forest-bed of Norfolk, which is proved by its vegetation to have been accumulated under temperate conditions, as well as in company with the Mastodon in the lower basin of the Mississippi. As the evidence stands at present, the Mammoth occupied the same area as the Cave-bear in the Early Pleistocene times, and is as clearly entitled to the first place in classification as the latter animal. If we consider the conditions under which the Pleistocene mammalia invaded Pliocene Europe, we can see at once why the Mammoth preceded the Reindeer. The temperate climate gradually became colder in France, Germany and Britain; and as the cold became more intense in the northern portions, the animals fitted for a cold climate passed southwards and westwards. In this great migration the animals adapted for a temperate or moderately severe climate would be the first to arrive. Were the climate of the extreme north to become so intense as to prevent the sojourn of the Reindeer and Musk-sheep on the shores of the Arctic Ocean, and to affect the whole of the Continent, there would be a steady drift of mammal life from north to south; the Elk and the Wapiti would invade the country of the Bisons, and leave their own district to be occupied by the Reindeer and the Musk-sheep. Indeed, speaking roughly, the zones of animal life which are centred round the north would not alter their relative position, but would be pushed further south, as it were, *en masse*. If the severity increased, the Reindeer would eventually reach the country of the Bisons, but only to find it in possession of the rearguard of Elks. From this analogy it follows that the animals which are now living in the temperate regions and which lived in Pleistocene Europe, arrived before their more arctic fellow immigrants. And if this be admitted, the Mammoth, the Irish Elk, and the Aurochs are at least as fairly entitled to occupy the first place in classification as the Cave-bear. In Britain the first of these animals has been obtained from the Forest-bed, as well as the Cave-bear, and is therefore of precisely the same relative antiquity. The foreign strata offer no evidence on this point.

A second objection to this theory is to be found in the fact that it presupposes that every collection of fossils found in a cave or river-deposit is likely to furnish a complete set of the animals living in the country at the time. The den of an Hyæna could hardly be expected to afford the same animals as those which are found in river-deposits; and the abode of a Cave-bear would most certainly contain a different suite of remains. If indeed the present distribution of animals be any clue to that of the Pleistocene, the very diversity which M. Lartet insists upon as representing different periods of time must necessarily have resulted from the same country being occupied by different animals at the same time. The Bear and Hyæna were living in the caves at the same time that the neighbouring river-valleys were occupied by the Mammoth, the Reindeer, and the Aurochs. Nor indeed does the classification apply even to the few cases on which the generalization is based. That of Aurignac*, for instance, is referred to the period of the Cave-bear, although the Reindeer, Mammoth, and Aurochs are also present. The caves of the Dordogne†, which have furnished such wonderful traces of the civilization of the hunter during those ancient times, are considered to belong to the Reindeer age, although the Mammoth has been found in no less than four out of the same series. A study of the distribution of these animals through the caves of France, Britain, and Germany has convinced me that three out of the four are worthless for the purpose of classification, since in the great majority of cases the four animals are associated together in the caves, and very generally also three out of the four in the river-deposits. And although the evidence seems pretty clear that the Reindeer arrived in Europe after these three animals, it competed with them for a very long time in the same area. As, also, the arctic climate gradually became temperate, it ought, *à priori*, to have been the first to retreat northwards, leaving the three others behind—the Aurochs to survive in the forests of Lithuania, and the other two to become extinct. We have no proof as to which of these became extinct first. The climatal change which was sufficient to banish the Reindeer from the south of France and from Central Germany had certainly not taken place during the latest stage of the Pleistocene; and the occurrence of that animal in the peat under the alluvium of the Thames, at Crossness, proves that it lived as far south as Kent in the Prehistoric age. In all probability, during some part of the vast interval which exists between the Pleistocene and the Prehistoric periods, it had become extinct in Central and Southern Europe, since it has not been discovered in any deposits in those regions which can be referred to the latter period. For these reasons M. Lartet's generalizations seem to me to be untenable, although it be true that the Cave-bear, Mammoth, and Aurochs arrived in Europe before the Reindeer, and the last-named animal departed from France and Germany before the Aurochs.

* See Ann. des Sc. Nat. Zool. 1861, p. 213.

† The materials for coming to a conclusion as to the Mammalia of Périgord have been afforded by the 'Reliquiæ Aquitanicæ' and the "Cavernes du Périgord" (Revue Archéol., Avril 1864), by M. Ed. Lartet and H. Christy, and by the examination of some of the remains in the Christy Museum.

Dr. Hamy* practically admits this to be the case when he follows Sir John Lubbock in classifying the caverns and river-deposits by the presence of the Cave-bear and Mammoth on the one hand, and of the Reindeer on the other, and by accommodating the theory to the facts by a series of transitions. But even his modification of M. Lartet's views does not explain the facts; for the "Station of Moustier," which he takes as the type of the series belonging to the age of the Mammoth, furnishes remains of the Reindeer, and those of Laugerie Haute and Laugerie Basse, which he refers to the age of the Reindeer, contain the Mammoth.

M. Dupont's† division of the caves of Belgium into the ages of the Mammoth and the Reindeer is equally unsatisfactory. In the Trou de Sureau, for instance, which he assigns to the former age, one Mammoth and many Reindeer were found; and in the other caves, which he assigns to the same date, more individuals were discovered of the Reindeer than of the Mammoth. In the Trou de Chaleux, which is referred to the later age, the Mammoth is found as well as the Reindeer.

Our present imperfect knowledge renders it impossible to subdivide the latest stage of the Pleistocene by means of the Mammalia, although the archæologists may be able to establish a rude sequence based on a comparison of the implements and weapons found in caves and the deposits of rivers. This principle of classification by the relative rudeness of such remains presupposes that the progress of man had been gradual, and that the rudest implements and weapons are the oldest. The difference, however, may have been due to different tribes or families having lived at the same time without intercourse with each other, as is now generally the case with savage communities, or to the supply of flint and chert for cutting-instruments being greater in one region than in another.

8. Range of Late Pleistocene Mammalia on the Continent.

The latest of the three divisions of the British Pleistocene fauna is widely spread throughout France and Germany and Central Russia. In the former country it has been proved by MM. Marcel de Serres, Lartet, Gaudry, Gervais‡, and others to have ranged from the English Channel to the shores of the Mediterranean, the only remains which have not been discovered in Britain being the Marmot, Chamois, Ibex, *Antilope saiga*, and striped Hyæna. In the following Table I have selected a few typical cases to show how the animals are associated together in various parts of France, Belgium, and Germany; and I have added those which have been discovered in

* Précis de Paléontologie Humaine, par le docteur G. T. Hamy, 8vo, Paris, 1870. Tableau I.

† Les temps Antéhistoriques en Belgique. L'Homme pendant les âges de la pierre. Par M. E. Dupont, 8vo, Bruxelles, 1871.

‡ M. de Serres, 'Les Oss. Foss. des Cavernes de Lunel Viel,' 4to. M. Lartet, *op. cit.* and 'La Seine,' par M. Belgrand, t. ii. 4to, 1871. M. Gaudry, a letter to the author; see also "Matériaux pour l'Histoire de l'Homme." M. Gervais, Zool. & Paléont. Françaises, 2nd edit., 4to, 1859; Nouvelles Recherches sur les animaux vertebrés, 4to, 1867–69.

	FRANCE.											
	Seine; Somme; River-deposits.	Grotte de la Combe Granal.	Grotte de Puy de l'Aze.	Grotte du Moustier.	Grotte des Eyzies.	Station de Laugerie Haute.	Station de Laugerie Basse.	Aurignac.	Provence.	Nice; Mentone.	Mars; Hérault.	Lunel Viel.
Homo palæolithicus ...	*	*	*	*	*	*	*	*	......	......	*	......
Spermophilus citillus ...	......	......	......	......	......	......	......	*	......	......	......	......
Arctomys marmotta......	......	......	......	......	......	......	......	......	......	*	*	......
Castor fiber	*	......	......	......	......	......	......	......	......	......	......	*
Lepus timidus	......	......	*	......	......	......	......	*	......	......	*	......
—— variabilis	......	......	......	......	......	......	......	......	......	......	......	......
—— cuniculus	......	*	*	......	......	......	......	......	......	......	......	......
—— diluvianus	......	......	......	......	......	......	......	......	......	......	......	*
Lagomys pusillus	......	......	......	......	......	......	......	......	*			
Mus lemmus												
Hystrix dorsata	......	......	......	......	......	......	......	......	*	......	......	......
Felis leo (var. spelæa) ...	*	......	......	*	......	......	......	*	*	......	......	*
—— pardus	......	......	......	......	......	......	......	......	......	......	*	*
—— lynx	......	......	......	......	......	......	......	......	......	*	......	......
—— caffer	......	......	......	......	......	......	......	......	......	......	......	*
—— catus..................	......	......	......	......	......	......	......	......	......	......	......	*
—— pardina	......	......	......	......	......	......	......	......	......	......	......	......
—— serval	......	......	......	......	......	......	......	......	......	......	......	......
Gulo borealis	......	......	......	......	......	......	......	......	......	......	......	......
Hyæna crocuta (var. spelæa)	*	......	*	......	......	......	......	*	*	*	......	*
—— striata	......	......	......	......	......	......	......	......	......	......	......	*
Mustela martes	......	......	......	......	......	......	......	......	......	......	......	......
—— putorius	......	......	......	......	......	......	......	......	......	......	......	*
—— erminea												
Lutra vulgaris	*	......	......	......	......	......	......	......	......	......	......	......
Ursus arctos	*	......	......	......	......	......	......	......	......	......	......	......
—— ferox..................	......	......	......	......	......	......	......	......	......	......	*	......
—— spelæus..............	......	......	*	......	......	......	......	......	......	*	......	*
Canis lupus	*	*	*	......	......	......	*	*	......	*	......	*
—— vulpes	*	*	*	......	......	......	......	*	......	*	......	*
—— lagopus...............	......	......	......	......	......	......	......	......	......	......	......	......
Elephas primigenius ...	*	......	*	*	......	*	*	*	......	......	......	......
—— antiquus	*	......	......	......	......	......	......	......	*	......	......	......
—— africanus	......	......	......	......	......	......	......	......	......	......	......	......
Equus caballus............	*	*	*	......	*	*	*	*	......	*	......	*
Rhinoceros tichorhinus	*	......	......	......	......	......	......	*	......	......	......	......
—— hemitœchus	*	......	......	......	......	......	......	......	*	*	......	*
—— megarhinus	......	......	......	......	......	......	......	......	......	......	......	......
Bos urus	*	?	?	......	?	?	?	?	*	?	......	*
—— bison	*	*	*	......	*	*	*	*	......	?	......	......
Ovibos moschatus	*	......	......	......	......	......	......	......	......	......	......	......
Capra ibex	......	*	*	......	......	......	......	*	......	*	......	......
Capella rupicapra	......	*	......	......	*	*	*	......	......	......	......	......
Antilope saiga †												
Sus scrofa	*	*	*	......	......	......	......	*	*	......	......	*
Cervus elaphus............	*	*	*	......	......	......	......	*	*	*	......	*
—— capreolus	*	......	......	......	......	......	......	*	......	*	......	......
—— megaceros	*	......	......	......	......	*	......	*	......	*	......	......
—— tarandus	*	......	*	*	*	*	*	*	......	......	......	......
—— dama	......	......	......	......	......	......	......	......	......	......	......	......
Hippopotamus amphibius (var. major) ...	*	......	......	......	......	......	......	......	......	......	......	......
—— Pentlandi	......	......	......	......	......	......	......	......	......	......	......	......

† *Antilope saiga* has been found

BELGIUM.										PLEISTOCENE MAMMALIA.			
Caves of Schmerling.	Trou de Magrite.	Trou de Sureau.	Trou de Naulette.	Trou de Chaleux.	Trou de Nutons.	Suabia.	Switzerland.	Prussia.	Bavaria: Gailenreuth.	Spain.	Gibraltar.	Italy: Val di Chiana, Rome.	Sicily.
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*	?	?	?	?	?	*	*	*					
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in the cave of Bruniquel.

the areas south of the Alps and Pyrenees which cannot with any certainty be said to belong to one stage of the Pleistocene rather than to the other. The *Antilope saiga* has been added to the list of the French Mammalia by M. Lartet from remains found in the cave of Bruniquel. The caves of Mentone, explored by Mr. Moggeridge *, and the caves and river-deposits of Provence are remarkable for the absence of the Reindeer, which is so abundant in those of the Pyrenees.

The same group † of animals has been proved to have occupied Belgium by the researches of Dr. Schmerling and M. Dupont; while their range is extended into Suabia by the investigations of Prof. O. Fraas, and into Switzerland by Dr. Rütimeyer. They also passed eastwards, and are found in the caves of Bavaria; and the more characteristic forms (such as the Mammoth, Woolly Rhinoceros, Musk-sheep, Reindeer, and Bison) have been traced through Russia in Europe by Pallas, into Northern Asia, where they have been met with in vast abundance by many explorers ‡.

9. The Middle Pleistocene.

The middle division of the Pleistocene, or that stage which is represented in Britain by the older deposit in Kent's Hole and the brick-earths of the Thames valley, is represented by a river-deposit in the Auvergne, which contains *Machærodus latidens*, and the cave of Baume, in the Jura, in which *Machærodus* occurs in association with the Cave-bear, Hyæna, Elephant, and a non-tichorine species of Rhinoceros. The distinctness of *M. latidens* from any of the Pliocene species has been satisfactorily decided by Prof. Gervais. The animal may therefore be taken as characteristic of a non-Pliocene era in the history of the animals of Europe; and since, on the one hand, the entire Arctic group of animals, so characteristic of the Late Pleistocene stage, is absent, and, on the other, all the peculiar animals of the early stage represented by the Forest-bed, that era must be Middle Pleistocene §.

10. The Early Pleistocene Division.

The river-deposit of St.-Prest, near Chartres, represents in France, according to Prof. Gervais, the Early Pleistocene stage of the Forest-

* Brit. Assoc. Meeting 1871, Edinburgh; Congrès International d'Anthropologie & d'Archéologie préhistoriques, Paris, volume for 1867, p. 96.

† The authorities for this list are the following writers:—For France and Belgium, those which have been quoted, Lartet, Christy, Gervais, Gaudry, De Serres. For those of Belgium, Dr. Schmerling, 'Les Oss. Foss. des Cavernes de Liège.' Suabia: Dr. Fraas. Switzerland: Dr. Rütimeyer. Prussia: Sir Charles Lyell, 'Antiquity of Man;' Giebel 'Paläontologie,' Quedlinburg, 1851, p. 32. Spain: M. Lartet, 'Ann. des Sc. Nat.' Gibraltar, Italy, Sicily: Falconer, 'Palæont. Memoirs,' vol. ii.; Busk, 'Prehistoric Congress,' Norwich, 1868.

‡ Middendorff, 'Sibirische Reise.' Wrangel, 'Siberia and the Polar Sea,' transl. by Major Sabine, 1840.

§ The authorities for this paragraph are:—Gervais, 'Zool. et Paléont. Franç., article *Machærodus*; 'Animaux vertébr.' 1867–69, p. 76; Lartet, 'Congrès International d'Anthropologie et d'Archéologie préhistoriques,' Paris, p. 269.

bed in this country. It contains the *Cervus carnutorum* and *Trogontherium Cuvieri*, in association with the Pliocene *Rhinoceros etruscus* and *Elephas meridionalis*, the two former of which are peculiar to it and the forest-bed. Although, therefore, there is no trace that any of the Northern Asiatic animals had yet arrived in Europe, the group most probably belongs to the early Pleistocene, since it is characterized by the presence of two non-Pliocene animals *.

11. Pleistocene Fauna of Southern Europe.

The fauna of Italy and Spain is remarkable for the absence of the Arctic forms which were so abundant in Central France and Germany; and there is no doubt that the difference between the fauna of the region north of the Alps and Pyrenees and that of the south is due to a difference of latitude and to the fact that the climatal change so marked in the north was hardly felt in the south. In other words, the physical condition of Britain during the early stage of the Pleistocene, and which did not recur again, was maintained throughout the Pleistocene period in the districts above mentioned. It is therefore no wonder that in the Pleistocenes of Italy we find the Mammoth associated with *Rhinoceros etruscus*, *R. megarhinus*, *Elephas antiquus*, and the Hippopotamus in the valley of the Tiber, and in the Val di Chiana with the Urus, Bison, and Irish Elk, just as in the Forest-bed of Norfolk †. But it does not follow from this that the Italian deposits are synchronous with the Forest-bed; for it is almost certain that, while the arctic mammalia were invading North-eastern Europe and had taken possession of Britain and the north of France, the Pliocene fauna of the south was scarcely affected; and it is reasonable to suppose that, even while the climate of Europe was lowered to the utmost in the Glacial period, the cold was not sufficient to allow of the invasion of the southern latitudes by the Arctic group of mammalia. The same observation applies also to Spain, in which M. Lartet has identified the African Elephant and the Striped Hyæna, as well as palæolithic implements, near Madrid.

The explorations of Capt. Broome ‡ in the caves of Gibraltar prove that the Grizzly Bear, Spotted Hyæna, Panther, *Rhinoceros hemitœchus*, Ibex, and many other animals mentioned in the above list lived in the Iberian peninsula during the Pleistocene age. In both Italy and Spain at that time the facies of the animal life was southern, and was not subject to those changes which are observable in Britain and France.

Fauna of Sicily, Malta, and Crete.

The investigations of Dr. Falconer § in the caves which occur in

* Lartet, 'La Seine,' par M. Belgrand, vol. ii. p. 206. Gervais, 'Animaux vertébrés vivants et fossiles,' 4to, 1867–69, p. 32.

† Falconer, 'Palæont. Memoirs,' vol. ii. p. 242.

‡ 'International Congress of Prehistoric Archæology,' Norwich, 1868, p. 106; Quart. Journ. Geol. Soc. vol. xxi. p. 364.

§ Quart. Journ. Geol. Soc. vol. xvi. p. 99; Palæont. Memoirs, vol. ii. p. 545.

the Hippurite limestone near Palermo, in Sicily, show that the Mammoth, which ranged as far south as the valley of the Tiber, did not cross the straits of Messina into Sicily. In the Grotto di San Ciro and in the Grotto di Maccagnone, from which vast quantities of bones have been exported from time to time for use in sugar-refining, a fauna was discovered differing in most important respects from that which has been described. Although the *Elephas antiquus* and the Spotted Hyæna remind us of the like deposits in the caves of Gower or Kirkdale, they were associated with the African Elephant and a small extinct Hippopotamus (*H. Pentlandi*). The last-named animal has been discovered by Dr. Adams and Captain Spratt* in the caves of Malta, along with a gigantic Dormouse (*Myoxus melitensis*) and two pigmy Elephants (*E. melitensis*). It has also been identified by Dr. Falconer † in the island of Candia. There is also proof of its having lived on the mainland of Greece, since an upper true molar, discovered by Dr. Rolleston, F.R.S., in a Greek tomb near Megalopolis in 1871, certainly belongs to this species, and was most probably obtained from one of the many caves which traverse the limestone plateau of Greece.

12. The Pleistocene Climate.

We have now to consider the conditions under which such an extraordinary fauna as this lived in Europe during the Pleistocene times; and the inquiry will lead us into some very interesting problems relating to the ancient climate and geography. The Pleistocene mammalia may be divided into five well-marked groups:—the first embracing those which live now in hot countries; the second those which inhabit northern regions or the tops of lofty mountains, where the cold is severe; the third those which inhabit temperate regions; a fourth those which are found alike in cold and hot; and a fifth those which are extinct.

The Southern Group of Animals.

The group of Pleistocene animals now found only in southern climates consists of eight. At the present day the Lion is found, with but extremely slight variations, in the whole of Africa—with the exception of Egypt and the Cape Colony, from which it has been driven by the hand of man. In Asia the maneless variety inhabits the valley of the Tigris and of the Euphrates and the districts bordering on the Persian Gulf; and in India the common form is met with, according to Mr. Blyth, in the province of Kattywar, in Guzerat. Although the animal is now found only in these hot regions, it is proved by the concurrent testimony of Aristotle, Pausanias, and Ælian to have inhabited the mountains of Thrace, in which the winter cold must have been severe. The animal, therefore, although from its present distribution better fitted for a tropical than a temperate climate, possessed suffi-

* Falconer, Palæont. Memoirs, vol. ii. p. 299. Spratt, Quart. Journ. Geol. Soc. vol. xxiii. p. 283. Leith Adams, Journ. Roy. Dubl. Soc. 1863.

† Palæont. Memoirs, vol. ii. p. 553.

cient elasticity of constitution to endure a considerable degree of cold. The second animal belonging to this section, the Spotted Hyæna, is now found only in South Africa, under tropical conditions; while the third, or the Hippopotamus, lives at the present time in Middle and Southern Africa. Formerly it inhabited the valley of the lower Nile; and a tooth in the British Museum, from Nubia, is as large as that of the fossil variety, *H. major*. In the Pleistocene period it extended over the whole of the regions north of the Mediterranean, from Sicily and Gibraltar as far as Kirkdale, in Yorkshire, and eastwards into the valley of the Rhine; and the Hyæna and Lion at least as far to the west as Hungary, and to the north as Königsberg. The evidence afforded by these three animals as to the climate of those portions of Europe which they inhabited in Pleistocene times, differs considerably in point of value, but, on the whole, points towards a temperate or comparatively hot condition; for, although the elasticity of constitution which we know to have been possessed by the Lion may also have been shared by the Hyæna, it is very improbable that so aquatic an animal as the Hippopotamus could have ranged from Southern Europe as far north as Yorkshire under any other than temperate conditions. It could hardly have endured a winter sufficiently severe to cover the rivers with a thick coating of ice, without having its habits entirely altered; and such an alteration of habit would certainly leave its mark in other modifications in the fossil remains than those minute differences which have been observed between them and the skeleton of the living *Hippopotamus amphibius*. The fourth species, or the African Elephant, ranged as far as Sicily, and, according to M. Lartet, as far in Spain as Madrid. The fifth, or the Striped Hyæna, so common now in North Africa, has, according to the same high authority, been discovered in Spain and, by M. de Serres, in the cave of Lunel Viel, in the south of France; and the *Felis caffer* of Desmarest, an African species, has been added, by Mr. Ayshford Sanford and the writer, to the British animals. The Serval and *Felis pardina* of Africa have been identified by Dr. Falconer and Prof. Busk among the remains from the caves of Gibraltar*.

The Northern Group.

The second group consists of those which are now only to be met with in the colder regions of the northern hemisphere—the Glutton, the Reindeer, Musk-sheep, Pouched Marmot, Hamster, Alpine Hare, Lemming, Ibex, and the Chamois; and their testimony as to climate is diametrically opposed to that of the preceding eight animals. The Musk-sheep, now found only in the high latitudes of the North-American continent, on the desolate, treeless, barren grounds, and the Reindeer, which lives in the belt of forest and the great treeless plains which extend between the forest and the sea, ranged through North Germany, Britain, and France, as far south as the mountain-barriers of the Alps and Pyrenees. Their absence from the districts further to the south is due, most probably, to a difference in tempe-

* Since the above was written, Professor Busk has informed me that he has detected *Felis caffer* among the remains from Gibraltar.

rature, rather than to an insurmountable mountain-range, since they are absent from Provence and Nice, on the French side of the Alpine barrier. The Pouched Marmot (*Spermophilus citillus*) of the Don and Volga, found its way as far west as Somersetshire; and the Hamster of Siberia extended as far west as Provence. The Alpine Hare, now found only in the colder climates of Northern Europe (with the solitary exception of Ireland), occupied the valley of the Rhine, at least as far down as Schussenried, in Suabia; and the Alpine Marmot lived then as now on the shores of the Mediterranean, near Mentone. The Ibex and Chamois ranged throughout Germany, as far north as Belgium, and occupied the south of France; and the former ranged as far to the south as Mentone and Gibraltar. The two carnivores now characteristic of the arctic regions, the Glutton and the Arctic Fox, have been discovered, the one as far to the south-west as Eastern France*, and the other as far as Schussenried; and at one time they doubtless occupied the whole of Germany and Northern Russia. The latter has not been found either in Britain or France. If the present habits of these animals be any index to their mode of life in the Pleistocene age, their presence in France, Germany, and Britain implies that the climate was severe, that it must have been analogous to that which they now enjoy on the tops of lofty mountains, or in the severe climate of the northern steppes in Asia and the high northern latitudes of America. But this conclusion is diametrically opposed by the evidence afforded by the Lion, Hippopotamus, and Spotted Hyæna. On the one hand, we meet with a group of animals throughout Italy and Spain and passing as far north as the latitude of Yorkshire, which are now peculiar to hot climates; on the other hand, we have a group of animals peculiar to cold climates, occupying in full force the whole of the region north of the Alps and Pyrenees. And the remains of these two groups of animals are so associated together in the caves and river-deposits of this region, that it is impossible to deny the fact that it was the common feeding-ground of both. And although it may be objected that the Spotted Hyæna, Lion, and *Felis caffer* may have been endowed with the same elasticity of constitution as the living Tiger, which is equally fitted to endure the severity of a Siberian winter on the shores of the Sea of Aral, and the intense tropical heat of Bengal, the same objection cannot be made to the Hippopotamus, because there is no case on record of any living species of herbivore being fitted at once for a cold and a hot climate.

The difficulty, however, offered by this conflict of testimony vanishes away, if we examine the conditions under which animals migrate from one area to another, according to the season. Sir John Franklin writes that the migrations of the animals in North America afford a means of foretelling the severity of the season. If the Reindeer retreat far south, then a severe winter is to be apprehended; if, on the contrary, they remain very nearly in their usual winter haunts, the season invariably is a mild one. The Reindeer of Northern

* Hamy, Paléontologie Humaine, p. 152.

Russia are equally dependent upon the season for their locality; and if an unusual season occurs, to put the animals off their accustomed route, the inhabitants of the district at the mouth of the Kolyma, living upon the chase, endure the severity of famine. M. von Matiuskin, the lieutenant of Admiral von Wrangel, had the good fortune to see one of the migratory bodies of Reindeer, consisting of many thousands divided into herds of two or three hundred each, in the act of crossing a river. By some such oscillation of temperature which regulates the supply of food for the herbivores, the remains of the animals of two contiguous zoological provinces may be found together in one spot, as in the case of the northward retreat of the Musk-sheep, which, living in Hearne's time (A.D. 1770) near Fort Churchill, has left that district to be occupied now by the Elk and Wapiti. In this manner the admixture of the remains of animals living at the present day respectively in a severe and in a temperate continental climate may be accounted for in the Pleistocene caverns and brick-earths. Sir John Richardson writes:—"The subsoil north of lat. 50° is perpetually frozen, the thaw on the coast not penetrating above 3 feet, and at Great Bear Lake, in lat. 64°, not more than 20 inches. The frozen substratum does not of itself destroy vegetable life; for forests flourish on the surface at a distance from the coast, and the brief, though warm, summer gives birth to a handsome flora, matures several pleasant fruits, and produces many carices and grasses." The climatal extremes of temperature are very great, the minimum winter temperature at Fort Reliance, on the northern shore of the Great Slave Lake (N. lat. 62°50′, long. 109° W.) being registered by Capt. Back, 17th Jan. 1834, as being −70°, and the maximum at the end of May +106°. These observations are confirmed by those of Sir John Franklin, at Fort Franklin (lat. 65°, long. 123°), where, on Dec. 25, 1826, the temperature was −43°, and on the 31st May +93°. Such a great variation as this could not have happened in the latitude of Britain, France, or Germany; nor is it required by the circumstances of the case.

In the vast plains of Siberia also, extending from the Altai Mountains to the Arctic Sea, we find a near approach to the Pleistocene climate of North-western and Central Europe. Covered by impenetrable forests, for the most part of birch, poplar, larch, and pine, and, in the north, of low creeping dwarf cedars, they present every gradation in climate, from the temperate to that in which the cold is too severe to admit of the growth of trees, which decrease in size as the traveller advances northwards, and are finally replaced by the grey mosses and lichens that cover the low marshy tundras. The minimum temperature registered by Admiral von Wrangel at Nishne Kolynisk on the banks of the Kolyma is −65° in January. "Then breathing becomes difficult, the wild Reindeer, that citizen of the polar region, withdraws to the deepest thicket of the forest, and stands there motionless, as if deprived of life, and trees burst asunder from the intensity of the cold. Throughout this area roam Elks, Black Bears, Foxes, Sables, and Wolves, that afford subsistence to the Jakutian and Tungusian hunters. In the northern part countless herds of

Reindeer, Elks, Foxes and Wolverines make up for the poverty of vegetation by the rich abundance of animal life. Enormous flights of Swans, Geese, and Ducks arrive in the spring, and seek deserts, where they may moult and build their nests in safety. Ptarmigan run in troops among the bushes ; little Snipes are busy among the brooks and in the morasses ; the social crows seek the neighbourhood of new habitations ; and when the sun shines in spring one may even sometimes hear the cheerful note of the Finch, and in autumn that of the Thrush." The hypothesis of a series of conditions in Europe, in Pleistocene times, similar to those of Northern Asia or of Northern America, would amply satisfy the difficulty of the case. In the Pleistocene winter the northern animals would pass southwards, and in the summer the southern forms would creep northwards ; and to this swinging to and fro of the animals, according to the seasons, the peculiar intermixture of their remains, over what may be called the debatable ground of Central Europe, may be accounted for, the head quarters of the northern animals being to the south-east of a line drawn from Yorkshire and Königsberg, and the head quarters of the southern being the regions bordering the Mediterranean.

It must be borne in mind that this mode of explaining the intimate association of the mammalia of the north and south, in the same deposit of the same river, does not imply that in one season a migration took place from the head quarters of each of these groups to the extreme point to which the remains of the animals of which it is composed occur, such as the Hippopotamus from the Mediterranean as far north as Kirkdale, or the Reindeer from the north as far south as the Alps. In the secular lowering of the temperature, the northern animals would compete with the southern for their feeding-grounds, according to the season. And this competition, if the climatal conditions were stationary, might be carried on, over a very small area, for a very long time—the debatable ground being a narrow band between the invaders and the animals in possession. There were probably many such pauses. Nor does it imply that there were no reversions to a warm, or temperate, state after the glacial conditions had begun in Northern Europe. One such reversion at least is proved by the physical evidence to have taken place ; but it has left no impression on the mammal fauna sufficiently marked for classificatory purposes. The Middle-Pleistocene mammalia may be the result of such a reversion, since the mixture of forms brought about by the southward advance of the northern animals would be the same as that of their retreat. The predominance of the northern over the southern animals in Central Europe implies that the winter cold during the Pleistocene age was more severe than it is now ; and this conclusion is corroborated by the condition of the river-deposits in which they are found in France and Britain. The contortions of the gravels and the angularity of the pebbles are, according to Mr. Prestwich, only explicable on the theory of ice having been formed in our rivers in far larger quantities than at the present day. The large plateaux of brick-earths were probably deposited by floods, caused by the sudden melting of the winter snow, similar to those which Admiral von Wrangel describes in Northern Siberia, and Sir John Franklin in the area north of the Canadian lakes.

The two other views which have been held as to the climate of the Pleistocene age must now be very briefly examined :—

1. Mr. Prestwich, fixing his attention more particularly on the evidence afforded by the contorted gravels and ice-borne pebbles in the river-deposits, has inferred that the climate was severe, and that the presence of the Hippopotamus in Britain may be accounted for on the hypothesis that it was clad in wool and hair, like the Mammoth. To this Sir John Lubbock objects that so aquatic an animal could not have lived here at the time that the rivers were frozen over. It seems to me also that such a change in the physique of the animal as Mr. Prestwich supposes could not have existed without leaving behind greater differences than we find between it and its living African representative. There were also other African animals in Britain, as well as the Hippopotamus.

2. The second view, or that of Sir John Lubbock and Mr. J. Geikie, accounts for the presence of arctic and African animals in Britain by the hypothesis that the one group occupied the country during a cold and the other during a hot period—in other words, that the swinging to and fro of the animal life depended upon secular, and not seasonal changes. Now, if this be true, we ought to find the remains of the animals in two distinct suites, in the river-deposits, corresponding to these climatal changes of long duration. We should find the Hippopotamus and Spotted Hyæna in those which were accumulated during the warm, the Reindeer, Glutton, and Marmot in those which were deposited in the cold period. After seeking for evidence of this for the last ten years, I cannot find the slightest trace of any such sequence in Britain or on the Continent. After the Pleistocene had fairly set in, as marked by the Forest-bed, and after the arctic mammalia had arrived, their remains are found lying side by side with those of the African species, *in the same river-strata*, and under the same physical conditions. Nor can this be accounted for by the supposition that the two series of remains have been accumulated at two *different* times, separated from one another by a wide interval—because in that case the one would be more decomposed than the other, or more rolled by water than the other. It is also a great demand on scientific faith to hold that in so many old river-deposits, as, for example, at Bedford, Acton Green, and Salisbury, the two series could by any possibility have been so intermingled as they actually are found to be, unless the animals to which they belong had been living at the same approximate time in the same region. This view is therefore untenable, so far as it is based on the false assumption that the remains occur in the river-strata in two distinct suites.

Mr. James Geikie, in a very able article in the 'Geological Magazine,' vol. ix. no. 4, brings forward the following objections to the view that the intermingling of the African with the Arctic species is due to climatal extremes :—

1. That the causes which induce the extremes of climate in the temperate zone of Northern Asia and America could not have existed in Britain. Before this objection can hold good, it is necessary to show what these causes are. Prevalence of wind in certain directions, writes Mr. Geikie (p. 166). This may be one of the causes; but at the same time it is one of the effects of change of temperature. The *vera causa* of the extremes in both cases seems to me to be that pointed out by Sir C. Lyell in the 12th chapter of the 'Principles' (1867)—the extension of a large mass of land from the equator to the polar circle. Such a mass of land extended from the range of Atlas northwards to the snowy regions of Scandinavia during the Pleistocene age (see Map, p. 436), the Mediterranean being reduced to two land-locked seas, and the mainland of Africa being continued on the one hand into Spain, and on the other, by Malta and Sicily, into Italy, and Greece extending so far south as to embrace Candia. Such an extent of land is surely an exact parallel to the two cases which I have quoted above; and climatal extremes must necessarily have been the result of the substitution of land for such a large area that is now covered by the sea. (See Map.) Mr. Geikie admits that at that time the winters were very much colder than they are now, because the higher mountains of Europe were also covered by *mers de glace*. Can he deny that the above geographical change in the Mediterranean area would have also left its mark in a higher summer temperature, other causes being put out of sight, than now? The inference that the summer temperature (p. 166) would be lower than at present in Britain, because there were glacier-areas in the north and in the higher districts in Central Europe, is inconclusive, since the mere existence of a glacier tells us nothing of the summer heat of the surrounding regions. Could we predicate, for instance, the temperature of the Subhimalayas from the contemplation of the glaciers of the central ridge? or the summer heat of Lombardy or of Provence from the glaciers of the Alps? Glaciers merely imply the existence of a certain line of mean annual temperature, *above* which the snow accumulates, and from which they are pushed down in some cases, as in New Zealand, to within a few hundred feet of the sea. It is obvious, therefore, that any argument from the Pleistocene glaciers to the summer heat is without value. All speculations as to the prevalent wind at that remote time in different parts of Europe appear to me mere guesses and nothing else.

2. The second objection is that the Hippopotamus is *not* a migratory animal. Is this so? It is true that its aquatic habits forbid its migration over the vast arid plains of Southern Africa, like the Antelopes; but, on the other hand, direct evidence for or against its migratory habits in a well-watered region is at present wanting. The remains found in Nubia, and preserved in the British Museum, certainly prove that once it ranged further north on the Nile than it does now. So far the evidence is in favour of its being a migratory animal. If its present range be compared with that during the Pleistocene it is impossible to deny that it *has* migrated from Africa to Yorkshire, or *vice versâ*.

3. The third is that the Hippopotamus could not have traversed vast distances, say from the south of France to Kirkdale, in Yorkshire, in one season. So far from holding this view, I have always maintained that in the vast lapse of time represented by the Pleistocene, or, as Mr. J. Geikie, speaking merely from the point of view offered by Scotland, terms it, the "Glacial Period," every inch of ground in Middle Europe was fought over by the invading and retreating forms, not at *one* time, but at *successive* times.

4. To the fourth objection (p. 167), that, under the conditions of climate to which I have referred, the vegetation of Britain would have been too scanty and meagre for the support of the animals, and that the destructive floods would reduce the lower grounds to a desert at the break-up of the winter, it is only necessary to refer to Wrangel's 'Siberia,' Middendorf's 'Sibirische Reise,' and Sir John Franklin's 'Overland Journeys,' to prove the existence of a luxuriant forest-vegetation in the region extending in Middle Siberia south of the Tundras, and in that south of the Barren Grounds, and the fact that large floods in the spring do *not* destroy the vegetation.

5. A further objection is based on the presence in some cases of *Unio littoralis* and *Corbicula consobrina* along with the mammalia in the river-deposits. Can we predicate temperature from either of these shells? The former still lives in the Loire; and the latter is abundant in the beds of the streams in the region of the Himalayas. The evidence as to the existing range of both these mollusks does not seem to me sufficient to trace any conclusion as to Pleistocene temperature.

The Temperate Group.

The third group of Pleistocene mammalia (which still inhabits the temperate zones of Europe, Asia, and America (is far larger than either of the preceding which we have described. It contains the

Musk-Shrew.	Wild Cat.	Brown Bear.	Saiga Antelope.
Beaver.	Marten.	Grizzly Bear.	Stag.
Hare.	Ermine.	Horse.	Roe.
Rabbit.	Stoat.	Bison.	Fallow Deer.
Porcupine.	Otter.	Urus.	Wild Boar.

In the Pleistocene this group of animals had very much the same range over Europe as they have at the present time, although many of the species have retreated from their ancient homes. Thus the Grizzly Bear, which then ranged from the shores of the Mediterranean into Great Britain, Central Germany, and Belgium, has retreated to its present stronghold in the Rocky Mountains. And although, unlike its more arctic associate in France and Britain, the Musk-sheep, it has not been recognized in European Russia or in Northern Asia, there can be little doubt that its line of retreat was eastwards by the Straits of Behring. The *Antilope saiga*, which then passed as far to the west as Auvergne, and the Musk-shrew, which has been discovered at Bacton, are now only living in the warmer regions of the Don and Volga, in Southern Russia. The latter animal is especially abundant on the banks of the Soura river, in lat. 55° N., and long. 47° E., under a temperate continental climate, cold in winter but hot in summer. Dr. Pallas, in his travels, describes the country which it inhabits as covered by tulips, saffron, and the Star of Bethlehem, in spite of the unusual severity of the preceding winter; and although the Pouched Marmot (*Spermophilus citillus*) was in the neighbourhood, there were vineyards close by. The Porcupine, on the other hand, does not now roam as far north as the caves of Belgium, but is restricted to the warmer countries near the Mediterranean.

The Pleistocene Urus still lives in the larger domestic cattle, although the wild breed was exterminated in the middle ages; and the Bison at the present time lives under the protection of the Tzar, in Lithuania, after having spread throughout Europe from Scania southwards. The Pleistocene Horse is represented by the mouse-coloured wild animal of Northern Asia; it was as abundant and as widely spread over the Pleistocene continent as the Urus and the Bison.

The presence of these animals in the Pleistocene fauna implies a climate not very severe, but in all probability resembling that of Southern Russia and Northern Asia, in which they now live.

The Species common to Cold and Tropical Climates.

The Panther, which has been found alike in Britain, France, and at Gibraltar, has at the present day a most extended range through Africa, from Barbary to the Cape of Good Hope, and throughout Persia into Siberia. In this latter country Dr. Gothilf Fischer describes it as living in the same districts in the Altai Mountains and in Soongaria as the Tiger. The Fox and Wolf are like instances of carnivores being able to endure great variations in temperature without being specifically modified. These three animals, therefore, can tell us nothing as to the Pleistocene climate.

The Extinct Species.

The extinct mammalia may be divided into three classes, which correspond with three out of the four into which the living Pleistocene species naturally fall. To the southern belong the two Maltese dwarf Elephants, as well as *Elephas antiquus* and *E. meridionalis*, *Rhinoceros etruscus*, *R. megarhinus*, *R. hemitœchus*, and *Ursus arvernensis*, which passed from their head quarters, in the districts bordering on the Mediterranean, as far north as Norfolk. The Mammoth and Woolly Rhinoceros constitute the second or northern division. Found throughout Northern Asia together, even on the shores of the great Arctic Sea, they ranged through Russia and the whole European area south of the Baltic and north of the Alps. The Mammoth even ventured as far south in Europe as the valley of the Tiber, and in America as far down as the lower basin of the Mississippi. From its presence, in association with the southern forms, mostly of Pliocene descent, in the Forest-bed and in Rome, as well as its more southern range, it must have been better adapted for living in a temperate or comparatively warm climate than the Woolly Rhinoceros.

The third group, which was probably fitted for a temperate climate, since it occurs neither in the north nor the south of Europe, consists of

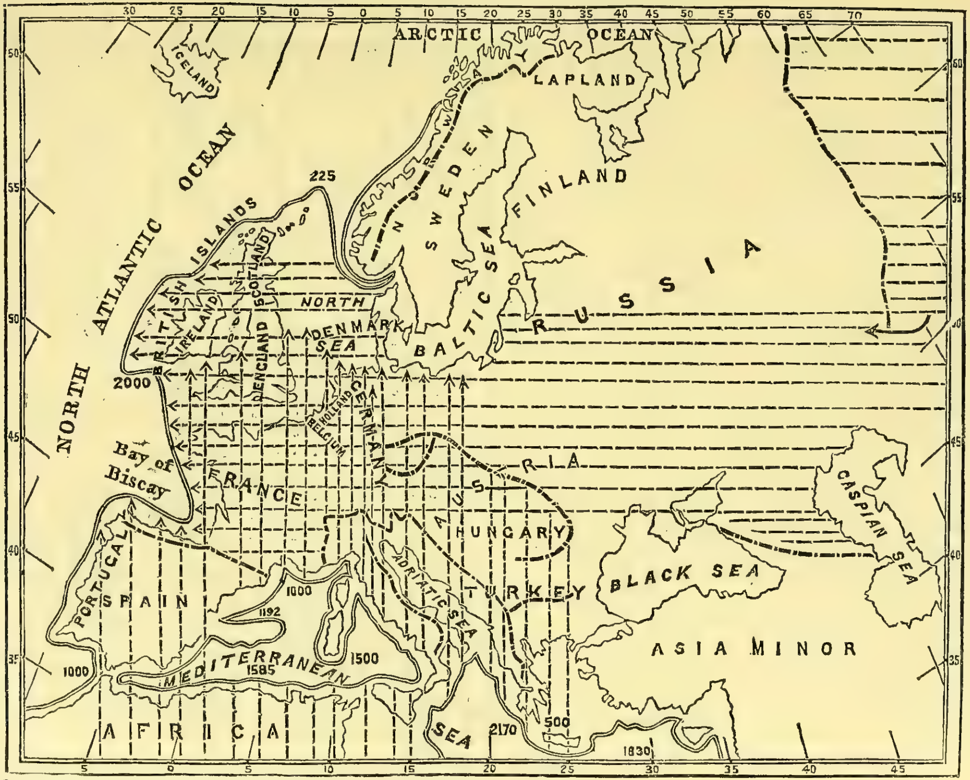
Trogontherium Cuvieri.	Cervus megaceros.
Machærodus latidens.	C. Browni.
Cervus carnutorum.	C. Sedgwickii.
C. verticornis.	C. Polignacus.

The last species, like *Elephas meridionalis*, is a Pliocene animal which survived into the early Pleistocene stage, and has been discovered by MM. Croizet and Jobert in the lacustrine deposit of Mont Perrier, and identified by Dr. Falconer as occurring also in the Forest-bed. *Trogontherium Cuvieri* and *Cervus carnutorum* are found alike in the Forest-bed, and the deposit of St.-Prest at Chartres, while the *Machærodus latidens*, of Kent's Hole, is found as far south as Auvergne and a cave in the Jura. The Irish Elk ranges, in space, from Scania as far as the valley of the Po—and in time, from the Forest-bed era down to the prehistoric peat-bogs, being far more abundant in the Prehistoric than in the Pleistocene strata. It has not, however, been discovered in the latter further north than Quedlinburg, on the Continent, and Kirkdale cave, in Great Britain, although in the prehistoric deposits of Scania it is comparatively abundant (Nilsson, MSS.).

13. The Three Climatal Zones.

The inference as to the Pleistocene climate of Europe drawn from the range of the Pleistocene species which are still living is corroborated by an appeal to those which are now extinct; and, treating the whole mammalian land-fauna as one, we have three great climatal zones, marked out by the varying range of the animals—the northern (see Map, p. 436), into which the southern forms never penetrated, the southern, into which the northern species never passed, and an intermediate area in which the two found are mingled together. The latitude of Yorkshire is the extreme northern boundary which the southern forms never passed; and a line passing through the Alps and the Pyrenees is the limit of the range of the northern animals, properly so called. In the head quarters of the Reindeer and Musk-sheep in Scandinavia and Northern Russia, the climate must have been like that of those regions which they now inhabit; and in the head quarters of the *Rhinoceros etruscus*, *E. meridionalis* and *E. antiquus*, of the Spotted Hyæna, and the Hippopotamus it was most probably hot. In the following map the three zones are marked, the northern by horizontal, and the southern by vertical broken lines; while the intermediate area, in which the northern and southern animals were associated together, is represented by the crossing of the lines.

Map of the Pleistocene Geography of Europe.



The double line represents the probable outline of the Pleistocene land.
The vertical broken lines show the range of the southern Mammalia, and the horizontal ones that of the northern forms.

14. The Physical Evidence as to Climate.

The actual existence of two out of the three climatal zones during the Pleistocene age is amply proved by the physical evidence of the Pleistocene strata, and altogether irrespectively of the mammalia. The researches of many eminent observers prove that after the close of the Forest-bed era the temperature of Northern Europe gradually became lowered, until it became arctic in character, and the complex phenomena were manifested which we call glacial—the deposit of clays with large angular and scratched blocks, the grooving, polishing, and rounding of the tops of hills and of the bottoms of valleys, and the accumulation of marine gravels.

At the commencement of the Glacial period in Britain an enormous ice-sheet, similar to that under which Greenland now lies buried, extended from the hills of Scandinavia over North Germany, the North Sea, Scotland, Ireland, Cumbria, and the lower portion of England, as far south as the line of the Thames valley, leaving the grooved hill-tops and the Boulder-clay to show its extension *. The land then most probably, as Mr. Godwin-Austen, Prof. Ramsay, and Sir Charles Lyell believe, stood higher than it does now. To this succeeded a period of depression, during which the mountains of Wales and the hills of Derbyshire and Yorkshire were submerged to a depth at least 1300 feet below their present level; and the waves of the sea washed out of the Boulder-clay the shingle and sand which constitute the "middle drift" of the north of England, Scotland, and Ireland †. Then the region north of the Thames valley was reelevated, and a period of glaciers set in, which, however, were of far less extent than those which preceded them, occupying isolated areas, and not uniting to form a continuous icy mantle to the country. There may have been, and probably were, many more changes in climate and geography than these three; but these are clearly and definitely marked in the whole of Britain north of the valley of the lower Thames, while the subdivisions are not so clearly traceable, and may be mere local phenomena ‡.

From this it follows that there were at least three well-marked changes in the Pleistocene climate of Great Britain, if not of Northern France. The temperature of the Forest-bed era was lowered until it reached a minimum that found expression in the great continuous ice-sheet moving resistlessly down to the sea, over the lower hills and valleys, and traversing hills as high as 2500 feet §. 2ndly. Then, coincident with the marine depression, the climate became warmer, until certain southern mollusks, such as *Cardium rusticum*, found

* Sir Charles Lyell has given an admirable summary of the glacial phenomena of Europe in 'The Antiquity of Man.'

† For information regarding the Irish Drift I have to thank Mr. Kinahan, of the Geological Survey of Ireland. See also papers by Harkness and Hull, Geol. Mag. vols. vi. & viii.

‡ On this point see Mr. J. Geikie, Geological Magazine, No. 93, "On Changes of Climate in the Glacial Epoch."

§ According to Jamieson, the top of Schehallion (Perthshire) is traversed by striæ which pass over from a northerly direction. Quart. Journ. Geol. Soc. xxi. p. 162.

favourable conditions of existence in the seas which then covered Lancashire. 3rdly and lastly. On the land emerging from the sea, the isolated glacier-areas show that the climate was severe, but yet not so severe as in the time of the continuous ice-sheet. On the Continent the traces of this lowering of the temperature are to be found in the travelled blocks and the Boulder-clay, which occupy the whole region north of the continuation of the line passing through the Thames valley eastward into Russia. To the south, however, of this line there is no evidence of a continuous ice-sheet—a fact which can only be accounted for by the climate at the time having been less severe than in the northern region. Nevertheless a *mer de glace* extended far over the Jura from the lofty axis of the Alps; and glaciers have left their unmistakable moraines in the valley of the Rhine, at least as far down as Suabia, as well as in Lombardy. The Alps, indeed, formed an axis, from which the ice extended far down on every side into the lower districts. M. Desor has proved that the three climatal changes which are so marked are traceable also in Switzerland. The lignite beds of Dürnten, which have furnished the remains of *Elephas antiquus*, rest on an ancient moraine, and are also covered by a mass of glacial detritus. It is clear, therefore, that before the accumulation of the lignite the cold was sufficiently intense to allow of glaciers occupying the horizon, that during the growth of the trees on the spot the glaciers had retreated, and that subsequently there was a reversion to the intense cold of the first Glacial period. These three changes have not been traced in any other part of the Continent.

The moraines and *roches moutonnées* and detritus which cover the flanks of the Pyrenees prove that they formed an axis from which the glaciers radiated into France and Spain. And similar remains detected by M. Delanoue in the valley of the Dordogne prove that the higher region of Auvergne was also covered with ice.

The mere fact of these glaciated areas being isolated shows that the Pleistocene climate was less severe in Central than in Northern Europe, although the angular condition of the superficial detritus, pointed out by Mr. Godwin-Austen, in the south of England, and the twisted and contorted river-gravels of Britain and Northern France, noted by Mr. Prestwich, that have been disturbed by the contact of ice, imply a temperature considerably lower than that which is now found in those countries.

On physical grounds, therefore, we have reason to believe that in the Pleistocene period, treated as a whole, there were two distinct climatal zones—the arctic, which extended as far down as a line passing through the valley of the Thames eastwards, and a zone with cold winter and warm summer, which extended from this line as far south as the Alps and Pyrenees. In the one the northern division of the Pleistocene mammalia found their head quarters, while the other afforded a common feeding-ground for both northern and southern animals. And the northern boundary of the latter gradually passed northwards, as the temperature became warmer, as far as the shores of the Baltic, probably in the latest stage of the Pleistocene.

15. Relation of the Pleistocene Mammalia to the Glacial Period.

The relation of the Pleistocene mammalia to the Glacial age, or the age of maximum cold, must now be considered. Did they invade Northern and Central Europe during the first or the second Glacial period, before or after the marine submergence indicated by the "middle drift"? We might expect, *à priori*, that as the temperature became lowered, the northern mammalia would gradually invade the region occupied before by the Pliocene forms; and such a mingling of Pleistocene and Pliocene animals we find in the preglacial forest-bed. Traces of such an occupation would necessarily be very rare, since they would be exposed to the grinding action both of the advancing glacial sheet, and, subsequently, to that of the waves on the littoral zone during the depression and reelevation of the land. At the time also that the greater part of Great Britain was buried under an ice-sheet they could not have occupied that region, although they may have been, and most probably were, living in the districts further to the south, which were not covered with ice. The labours, however, of Dr. Bryce and others have proved that one at least of the characteristic Pleistocene mammalia, the mammoth, as well as the reindeer, lived in Scotldan before the deposit of the Lower Boulder-clay; while Mr. Jamieson has pointed out that these animals could not have occupied that area at the same time as the ice, and therefore must be referred to a still earlier date. Dr. Falconer has shown that the mammoth occurs in the Forest-bed; and his conclusion, which seemed to be doubtful, has been verified by fresh discoveries. The teeth and bones discovered in the ancient land-surface at Selsea also very probably indicate that the mammoth lived in Sussex before the glacial submergence, although they were never admitted by Dr. Falconer to be of the same age as the remains of *Elephas antiquus* from the same Preglacial horizon. On a careful reexamination of the whole evidence, I am compelled to believe with Mr. Godwin-Austen and Mr. Prestwich that the *à priori* argument that Pleistocene mammalia occupied Great Britain before the Glacial period is fully borne out by the few incontestable proofs that have been brought forward of the remains having been found in Preglacial deposits. And the scanty evidence on the point is just what might be expected from the rare accidents under which the bones in superficial deposits could have escaped the grinding of the ice-sheet, and the subsequent erosive action of the waves on the coast-line. The arrival of the northern and temperate Pleistocene mammalia in Britain in Preglacial times implies that they were living on the Continent before the low glacial temperature had set in. On the other hand the evidence is conclusive that they lived in Britain and on the Continent after the intense glacial cold had passed away, since their remains are found in deposits which rest on Boulder-clays. At Schussenried, for example, the reindeer, glutton, bear, and other animals were found by Prof. Fraas in a deposit which rested on the surface of the terminal moraine of the glacier of the

Rhine, which must therefore have retreated at the time the remains were accumulated by Palæolithic man. Prof. Carl Vogt's observation that the same fauna and flora occupied Europe before, during, and after the period of intense cold, seems to me to be amply proved by the discoveries at Dürnten, to which allusion has been made, and many others. The Glacial period can therefore no longer be viewed as a hard and fast barrier, separating one fauna from another, as Sir C. Lyell has shown; and the terms Preglacial, Glacial, and Postglacial cannot be considered of any value in the classification of the mammalia. And although the earliest traces of man found in the river-deposits of Great Britain can be proved from their position to be of Post-boulder-clay age, the Brick-earth of Crayford excepted, it by no means follows that those which have been furnished by the caves of the south of England, or of the south of France, are also of the same age; and since the fauna amongst which he lived arrived here before the intense arctic severity of the glacial maximum had been reached in Britain, it is very probable that he came at the same time. In other words, if man be treated merely as a Pleistocene animal, there is every reason for the belief that he formed one of the North-Asiatic group, which was certainly in possession of Northern and Central Europe in Preglacial times. He occupied the area north of the Alps and Pyrenees with the animals of that group, and disappeared with them at the close of the Pleistocene period, and therefore may fairly be assumed to have arrived in Europe in their company.

16. The Pleistocene Invading Forms.

If the Pleistocene mammalia be compared with those of the Pliocene strata of Auvergne, Montpellier, and the Val d'Arno, it will be seen that the following animals were not known in Europe before the Pleistocene age.

Man.	Panther.	Musk-sheep.
Musk-shrew.	*Felis caffer,*	Ibex.
Pouched Marmot.	*Felis pardina.*	Chamois.
Alpine Marmot.	Serval.	*Antilope saiga.*
Hamster.	Cat.	Irish Elk.
Hare.	Spotted Hyæna.	Reindeer.
Alpine Hare.	Brown Bear.	*Cervus Browni.*
Rabbit.	Grizzly Bear.	Stag.
Lepus diluvianus.	Cave-bear.	Fallow Deer.
Lemming.	*Machærodus latidens.*	Roe.
Beaver.	Arctic Fox.	*Cervus verticornis.*
Trogontherium Cuvieri.	Mammoth.	*C. Sedgwickii.*
Lion.	Woolly Rhinoceros.	*C. carnutorum.*

The African Elephant and the Pentlands small Hippopotamus are added by the caves of Sicily, and the pigmy Elephants and the gigantic Dormouse by those of Malta.

17. The North-western Extension of Europe.

The Pleistocene mammalia may be divided into three groups—those derived from Northern and Central Asia, those derived from Africa, and those which were living in the same area in the Pliocene age. The migration of the first two groups into Europe at the close of the Pliocene age throws a very great light on the ancient geography. Had not the animals which lived in Europe during the Pliocene age been insulated by some physical barrier from those which invaded Europe from Asia, the latter would occur in our Pliocene strata as well as the former, and we might have had the mammoth and the mastodon associated here as well as in North America. Such a barrier is offered by the northern extension of the Caspian along the low-lying valley of the river Obi; and that the Caspian has extended further north than now in comparatively modern times has been proved by Dr. Pallas. It is therefore very probable that this was the barrier which divided the Pliocene mammalia of Europe from those animals which were living at the time in Asia, and which subsequently passed into Europe. The animals of Northern and Central Asia could not pass westwards before this barrier was removed by the elevation of the sea-bottom between the Caspian sea and the southern portion of the Urals. When this took place the Musk-shrew, Lemming, Brown and Grizzly Bears, Mammoth, Woolly Rhinoceros, Musk-sheep, Reindeer, Stag, and Roe passed over into Europe *, those of them which were fitted for a temperate or moderately warm climate, such as the Stag, Roe, Brown and Grizzly Bears, passing down to the extreme southwest, while the rest did not go further to the south than the Alps and Pyrenees. Then there must have been a continuous mass of land extending from Northern Asia to the margin of the Atlantic, which has been proved by Mr. Godwin-Austen and others to have passed from Scandinavia to the west of the present coast-line of Ireland, of the south of England, and of France. [See Map, p. 436.]

18. The Southern Extension of Europe.

The same argument may be based on the African mammalia. The African Elephant could not have found its way northwards to Spain and Sicily, or the Serval to Spain, or the *Felis caffer* to Britain without an extension of the African mainland, so as to allow of the migration; and the same may be said perhaps of the Spotted Hyæna, although this animal, so widely spread through Central and Southern Europe, may have arrived by way of Asia Minor, as well as by a direct line, passing through Sicily and Gibraltar. Nevertheless, as Dr. Falconer has remarked, the area of the Mediterranean must have been very much smaller than it is now during the time that Malta, Sicily, and Candia were inhabited by the Pleistocene mammalia. The presence of *Hippopotamus Pentlandi* in these three islands proves that they were connected during the life-time of the animal; and this mass of land would afford a passage northwards to the African mammalia. The objection which is offered by the depth of

* This is very nearly the same view as that held by Dr. Brandt, Imp. Acad. St. Petersb., 'Zoogeographische und Paläontographische Beiträge,' April 4, 1867. See also Lartet, 'Comptes Rendus,' tome lxvi. p. 409.

the sea between Tunis and these islands, of over two hundred fathoms, does not at all invalidate the conclusion that there was actually such an extent of land, since that is a region in which at the present time land is being elevated and depressed irregularly by the exertion of those forces which find vent in Vesuvius and Etna. The great depth, however, of no less than 1400 fathoms, which intervenes between Candia and the mainland of Tripoli, offers a difficulty to the view that the land has been sunk to that depth since *Hippopotamus Pentlandi* lived in that island, and it cannot be quoted in favour of the continuity of land in that direction rather than towards Europe. The interval of a depth of sea of not more than 500 fathoms between it and Greece seems to me to imply that the island has been an appanage of Europe; and this conclusion is considerably strengthened by the recent discovery of *Hippopotamus Pentlandi* at Megalopolis, by Dr. Rolleston. I have therefore, in the Map, adopted the 500 fathom line as roughly indicating the ancient sea-margin.

The absence of the peculiar fauna of the caves of Malta in those of Sicily implies that the two areas were insulated from each other during the time that the pigmy Elephants and giant Dormouse were living in the former, and the African Elephant in the latter; for if this had not been the case the two faunas would have been likely to be mingled in regions which are now so nearly alike in climatal conditions. It is very possible that they may belong to two different stages of the Pleistocene; but this point cannot be decided until the Pleistocene faunas of Greece, Africa, and Asia Minor have been carefully compared and classified. The *Elephas antiquus* of Sicily points to a connexion by land with Italy, just as the *Elephas africanus* does to a connexion with Africa.

The striped Hyæna of the South of France and the Hippopotamus are Pliocene animals which survived into the Pleistocene age, and do not necessarily imply a direct continuity with Africa at the latter age; and the Lion and the Panther are as likely to have been derived from Asia as from Africa, since they now live on both those continents. The Chamois and the Ibex are most probably of North-Asiatic extraction, since they enjoy a climate that is not offered by the North-African continent. Of the rest of the animals it can only be said that they were unknown in Europe before the beginning of the Pleistocene age. In the Map (p. 436) I have represented the geography of the Mediterranean as implied by these animals, and corroborated in a striking degree by the evidence of the soundings. The barrier of land along which the African animals passed, on the one hand, into Spain, and on the other into Italy, is represented by portions of the sea-bottom which still stand far above the bottom of the Tyrrhenian and Ionian basins; and the depth is far less between the Morea and Candia than between the latter and Africa. The effect of a mass of land stretching, with but a slight break at the Mediterranean area, from the range of the Atlas to the extreme north of Europe, must necessarily have tended to produce extremes of climate similar to those which we now witness in masses of land similarly situated, such as Northern Asia and North America. And these climatal extremes have been deduced, as we have already seen, from the analysis of the Mammalia.

19. The Pliocene Mammalia.

The relation of the Pleistocene to the Pliocene fauna must now be examined; and this inquiry is of very great difficulty, because the latter has not yet been satisfactorily defined, although Prof. Gervais and Dr. Falconer have given the more important species of Auvergne, Montpellier, and the Val d'Arno. The following list is taken from Prof. Gervais's great work 'Zoologie et Paléontologie Françaises,' p. 349, the term Pseudo-pliocene merely implying that the fauna differs from that of the marine deposit of Montpellier, which he takes as his standard.

Pseudo-pliocene of Issoire.

Hystrix refossa.	Cervus ardens.	Canis borbonidus.
Castor issiodorensis.	C. cladocerus.	Felis pardinensis.
Arctomys antiqua.	C. issiodorensis.	F. arvernensis.
Arvicola robustus.	C. Perrieri.	F. brevirostris.
Lepus Lacosti.	C. æstuariorum.	F. issiodorensis.
Mastodon arvernensis.	C. pardinensis.	Machærodus cultridens.
Tapirus arvernensis.	C. arvernensis.	Hyæna arvernensis.
Rhinoceros elatus?	C. causanus.	H. Perrieri.
Bos elatus.	Sus arvernensis.	Lutra Bravardi.
Cervus polycladus.	Ursus arvernensis.	

To these animals Dr. Falconer * adds *Hippopotamus major*, *Elephas antiquus*, and *Rhinoceros megarhinus*, and he identifies *Rhinoceros elatus* with his new species *Rhinoceros etruscus*. Prof. Gaudry agrees with me in the belief that *Hyæna Perrieri* is identical with *H. striata* or the striped species.

Professor Gervais also identifies the *Equus robustus* of M. Pomel, from the same locality, with the common Horse, *Equus fossilis*.

The fauna of Montpellier is certainly very different from that of Issoire; but since it is neither Miocene nor Pleistocene, it must belong to one of the intermediate stages of the Pliocene. It includes

Semnopithecus monspessulanus.	Cervus Cuvieri.
Macacus priscus.	C. australis.
Chalicomys sigmodus.	Sus provincialis.
Lagomys loxodus.	Hyænodon insignis.
Mastodon brevirostris.	Hyæna —— ?
Rhinoceros megarhinus.	Machærodus.
Tapirus minor.	Felis Christolii.
Antilope Cordieri.	Lutra affinis.
A. hastata.	

The *Mastodon brevirostris* of this list is considered by Dr. Falconer to be identical with *M. arvernensis* of MM. Croiset and Jobert.

The fauna of the Val d'Arno differs from that of Montpellier and of Auvergne, and yet is considered by Dr. Falconer to be eminently

* Palæont. Mem. vol. ii. p. 49.

typical of the European Pliocene *. The animals identified by him in the museums of Italy are as follows:—

Felis.	Elephas meridionalis.
Hyæna.	Rhinoceros etruscus.
Machærodus cultridens.	R. megarhinus.
Mastodon arvernensis.	R. hemitœchus.
M. Borsoni.	Hippopotamus major.
Elephas antiquus.	

All these animals, with the exception of *Rhinoceros hemitœchus*, have been discovered in the Pseudo-pliocene of Issoire, while the Megarhine Rhinoceros and *Mastodon arvernensis* are the only two which have been obtained from the marine sands of Montpellier. The Pliocene animals, therefore, inhabiting Northern Italy are more closely allied to those of Auvergne than to those of Montpellier.

If these three localities be taken as typical of the Pliocene strata, we shall find that several of the species range as far north as Britain, and occur in deposits which, from the evidence of the mollusca, have been assigned to that age. *Mastodon arvernensis*, *Elephas meridionalis*, and *Ursus arvernensis*, have been obtained from the old land-surface which underlies the sand and shingle of the Norfolk Crag, in company with many forms of Deer and Antelopes which have not yet been identified, while the *Hipparion* is found in the marine crags of Suffolk.

The animals which especially characterize the Pliocene strata of Europe are *Machærodus cultridens*, *Mastodon arvernensis*, and *M. Borsoni*, besides the genus *Tapir*.

If this Pliocene fauna be compared with that of the Preglacial Forest-bed, it will be seen that the difference between them is very great. The Pliocene Mastodon Tapir, the majority of the Cervidæ, and the Antelopes are replaced by forms such as the Roe and the Red Deer, unknown up to that time. Nevertheless many of the Pliocene animals were able to hold their ground against the Pleistocene invaders, although, subsequently, as I have already shown, they disappeared one by one, being ultimately beaten in the struggle for existence by the new comers. The progress of this struggle has been used in the preceding pages as a means of classification.

20. Conclusion.

The following are the salient points of the Pleistocene age offered by the study of the land Mammalia in the area north of the Alps and Pyrenees.

The Pleistocene Period.

A. The latest stage.

Palæolithic Man.	Stag, comparatively rare.
R. tichorinus, abundant.	Northern forms of life in full possession of area north of Alps and Pyrenees.
Elephas primigenius, abundant.	
Reindeer, abundant.	

* Palæont. Mem. vol. ii. pp. 189, 190.

B. The middle stage.

Palæolithic man.
Machærodus latidens.
Stag, abundant.
Rhinoceros megarhinus, still living.
R. tichorhinus, present.
Northern forms of life present, but not in force.

C. The early stage.

The following animals are peculiar to this stage:—

Trogontherium Cuvieri.
Cervus verticornis.
C. Sedgwickii.
C. carnutorum.

The following make their appearance:—The Beaver, Musk-shrew, Cave-bear, Roe, Stag, Irish Elk, Urus and Bison, Wild Boar, Horse (?), Mammoth, Wolf, and Fox.

The Pliocene *Ursus arvernensis*, *Cervus Polignacus*, *Rhinoceros etruscus*, and *Elephas meridionalis* still living.

The Pliocene.

Mastodon arvernensis.
M. Borsoni.
Hipparion gracile.
No living species of Cervidæ.

The three subdivisions of the Pleistocene do not apply to the region south of the Alps and Pyrenees, because the northern group of animals did not pass into Spain and Italy. In these two latter countries we find that assemblage of animals living throughout the Pleistocene age, which in France and Britain lived only in the early stage.

Discussion.

Mr. Prestwich was hardly prepared to accept the proposed division of the Pleistocene mammalia into three groups—at all events so far as Britain was concerned. Neither could he draw that distinction between the beds at Erith and Grays and those higher up the Thames, which found favour with the author. The barrier offered by the river itself might to some extent account for the absence of Reindeer; and though there was a difference in the fauna in the two cases, it seemed hardly enough to mark any great distinction in time. As for the Hippopotamus, which occurred over the whole of Northern Europe, associated with the Musk-ox and large boulders, he could not see how the conclusion was to be escaped of its having been able to withstand greater cold than its present representative. Though the winters might have been colder, there was evidence in favour of the summers having been warmer; and the flora seems to have been much like that of the present day. The probable migrations of the different animal groups had already been pointed out by M. Lartet, though Mr. Dawkins had carried his investigation of the subject further. Mr. Prestwich called attention to the fact of the Mammoth having been found in Italy.

Mr. Charlesworth regretted that the author had not included within his province any of the marine Crag-deposits, some of which had been regarded as Pleistocene. In these beds the fish had been regarded by M. Agassiz as tropical in character, while M. Deshayes considered the molluscan remains arctic. A similar discrepancy had been observed in other deposits of the same series; and he considered, therefore, that it was unsafe to generalize from any one series of remains, as, unless the whole fauna was taken into consideration, it was probable that erroneous conclusions would be arrived at.

Mr. Flower considered that both on geological and palæontological grounds the ossiferous caves and the river-deposits were separable, and ought to be separated, and that no satisfactory results would be obtained by placing in the same category the Mammalian remains of a hundred and fifty rivers and a great number of caves of widely different ages and characters.

Mr. Evans observed that in generalizations of this kind not only the whole of the palæontological evidence should be taken into account, but the stratigraphical also. With regard to the author's middle division of the mammalia, he thought that eventually this would have to be modified. If it were to be maintained there would be a great difficulty in accounting for the presence of the high beds at Shacklewell and Highbury, as these, though in a valley confessedly excavated by the river, and regarded as of more recent age than the lower beds, would yet be at a far higher level. Though accepting the probable existence of man in preglacial times, he pointed out that up to the present time the beds in Britain in which his works had been found were all postglacial.

Mr. Boyd Dawkins, in reply, stated that, in forming his conclusions, he had not left out of view the evidence afforded by the classes of remains other than those of mammalia; but they threw no light on the classification. With regard to the middle of his divisions of the Pleistocene mammalia, he relied to a great extent on the presence of *Rhinoceros megarhinus*, and of a large number of Stags, to say nothing of the absence of the Reindeer. He did not attach so much importance to the question of the level, as in some cases (for example the Forest-bed of Norfolk) it was not a test of age. He gave his reasons for not regarding the Mammoth as an exclusively arctic animal. His remarks with regard to M. Lartet's classification referred rather to the expanded views of his followers than to those of M. Lartet himself. He acknowledged his obligations to MM. Gaudry, Fraas, Rütimeyer, and Nilsson for various facts which they had been kind enough to communicate to him.

June 19, 1872.

Richard Anderson, Esq., F.C.S., Uddingstone, near Glasgow; Lieut. Henry Allen Gun, R.E., South Kensington; Sir Victor Brooke, Bart., Colebrooke, Lisnaskea, Fermanagh, Ireland; Edmund James Smith, Esq., 16 Whitehall Place, S.W., and Peter Pickup, Esq., Townley, Burnley, Lancashire, were elected Fellows of the Society.

The following communications were read:—

1. *On* TROCHOCYATHUS ANGLICUS, *a* NEW SPECIES *of* MADREPORARIA *from the* RED CRAG.

By P. MARTIN DUNCAN, M.B., F.R.S., V.P.G.S., &c., Professor of Geology in King's College, London.

[PLATE XXVIII.]

CONTENTS.

I. THE coral about to be described was found in the Red Crag within the grounds of Great Bealings Rectory, Suffolk*. There is only one specimen; but it is so well preserved, and its anatomical details are so perfect, that there is no difficulty in giving the form a generic and specific appellation.

TROCHOCYATHUS ANGLICUS. Pl. XXVIII. figs. 1–4.

The coral is subhemispherical in shape, and has a small flattened base, upon which there are the marks resulting from the disruption of a former adhesion (fig. 4). The outside of the coral, from the cicatrix at the base to the calicular margin, is covered with a smooth, opaque, and plain epitheca. The epitheca hides the costæ, and is faintly ornamented superiorly with an indistinct "vandyke" pattern. The calice (figs. 1, 2) is nearly circular in its outline, is slightly inverted at the margin (which is broad), and is shallow. The columella is formed by the junction of the pali and by a small amount of proper tissue; it is small but prominent, and rises to a higher level than the septa at their junction with the pali. The septa are long, unequal, separate, and non-exsert; there are six systems of them; and there are the members of four cycles in each system. The primary septa are slightly larger than the secondary; and both dip down from the inverted margin of the calice into the fossa and come into contact with pali. The septa of the third cycle are smaller than those of the second, and are slightly wavy in their course. The septa of the fourth and fifth orders of the fourth cycle are smaller than the tertiary, to which they are united close to the junction of these septa with their pali. The septa are ornamented with large, acutely pointed, granular and papular elevations on their sides. This ornamentation is nearly confined to the columellar end of the large septa; but the septa of the third and fourth orders are granulated throughout their whole length. In their breadth the costæ are larger than the septa to which they correspond; they are moderately unequal, close, and triangular in outline; they are only visible at the calicular margin. The wall is seen in the form of a series of processes which pass between the adjacent costæ close to their junction with their respective septa. The pali of the third cycle of septa are the largest and most external; those of the secondary septa are distinct, but those of the primary are very small; all are granular. Some of the granular-looking papillæ of the higher orders of septa occasionally unite like synapticulæ.

Width of the calicular end $\frac{6}{10}$ inch; height of the corallum $\frac{2}{10}$ inch.

* Mr. C. J. A. Meyer, F.G.S., procured the specimen and obtained the details of its discovery.

II. This form is unlike any other from the British and Belgian crag deposits, and does not resemble any species from the Sicilian Tertiary deposits, from the Miocene of Western Europe, from the Eocene of England and the Paris basin, or from the littoral or deep-sea zones of the North Atlantic and Mediterranean Sea.

The closest approach in structural resemblance is in the instance of *Trochocyathus meridionalis*, Duncan*, which is a characteristic coral of the mid-tertiary deposits of Australia; the dense epitheca of the crag form distinguishes it at once; and the difference thus determined is specific.

The *Trochocyathi* of the type of *Trochocyathus Burnesi*, D'Archiac, from the Nummulitic strata of Sindh, and the subhemispherical *Trochocyathi* from the British Gault and Oolites foreshadowed the peculiar species under consideration.

The genus *Trochocyathus* has not yielded any recent species as yet; and the dredgings and searchings of the littoral and sublittoral zones of the British coasts have not produced a specimen. M. de Pourtales describes, with an expression of doubt, a worn coral from the Florida region as a recent member of the genus.

The distinctive characters of the new species are the dense epitheca, the small and prominent columella, and the inverted calicular margin.

III. The new species from the Red Crag belongs to the solitary or simple type of Madreporaria, which does not contribute forms to coral reefs. It may be compared with the broad-based *Caryophylliæ* of the Devonshire sublittoral zone in a technological sense; and it was probably a dweller in shallow water, on rocks where there was no mud accumulating.

The coral fauna of the Upper Tertiaries of England consists of six species:—

1. *Sphenotrochus intermedius*, Münster, sp.
2. *Trochocyathus anglicus*, Duncan.
3. *Flabellum Woodii*, Ed. & Haime.
4. *Cryptangia Woodii*, Ed. & Haime.
5. *Balanophyllia calyculus*, Wood.
6. *Solenastræa Prestwichi*, Duncan.

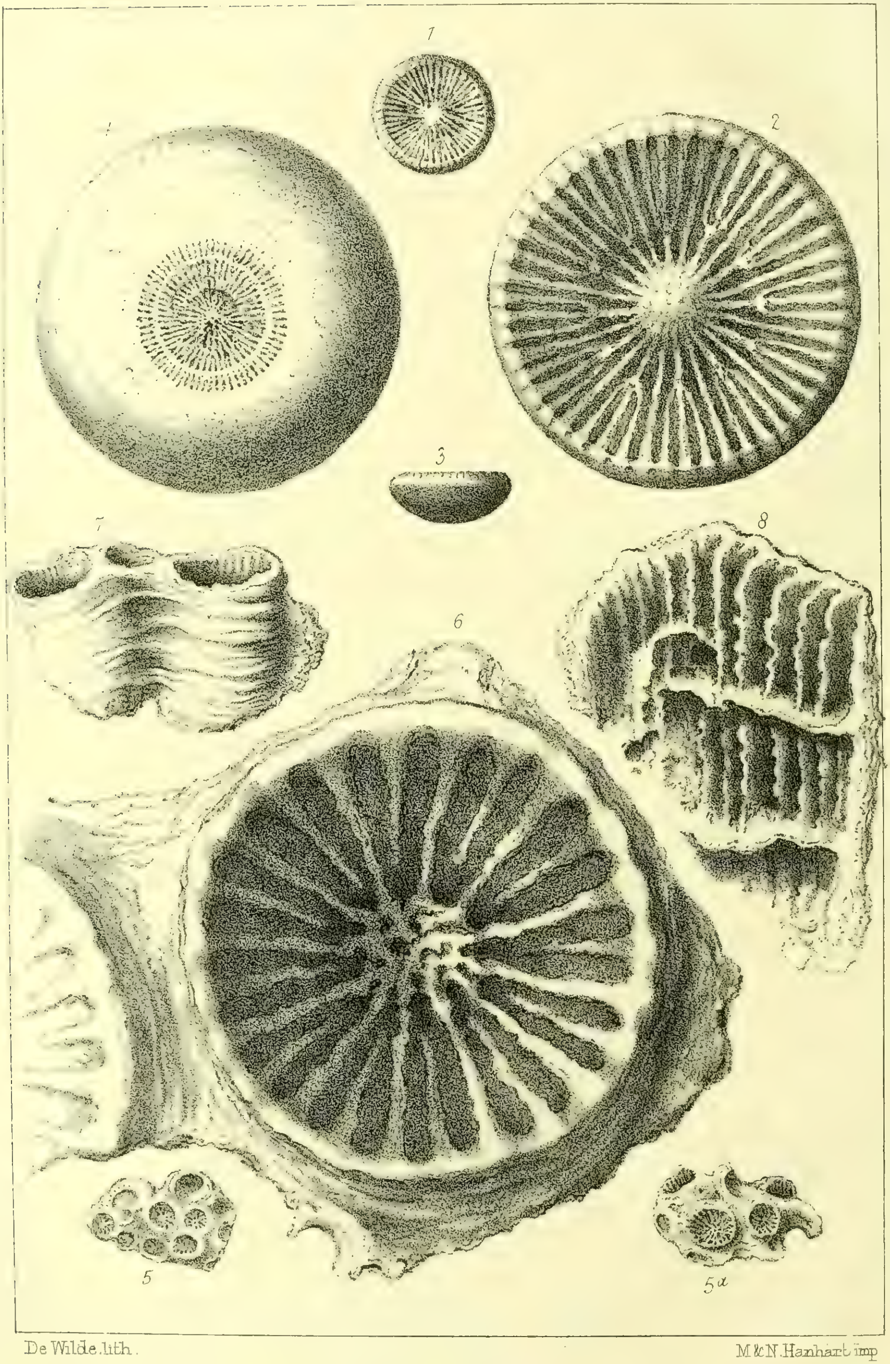
Sphenotrochus intermedius, under a variety of synonyms, exists off Cornwall, the west coast of Ireland, and Arran. It is a very common species in the Bay of Tangier, in the Straits of Gibraltar.

Trochocyathus anglicus, Duncan, is not represented, so far as the results of recent explorations tend to prove, in the existing European coral fauna.

Flabellum Woodii, Ed. & H., is represented by a fine *Flabellum* which is found in the neighbourhood of Cape Spartel, in the S.W. of Spain, in deep water. The curious *Cryptangia Woodii*, Ed. & H., belongs to a genus which appears to have become extinct during the age of the Crag.

There are many species of *Balanophyllia* in the North-Atlantic and Mediterranean area and on our coasts; and the Crag form indicates great vigour of coral life and abundance of food. It is extinct.

* Quart. Journ. Geol. Soc. vol. xxvi. p. 296, pl. xix. fig. 2.



De Wilde lith. M & N. Hanhart imp.

CRAG CORALS.

Finally, the *Solenastræa* I described in Quart. Journ. Geol. Soc. vol. xxvii. p. 369 is probably a *remanié* fossil*. It is remarkable that the present coral fauna of the British seas should be so poorly represented in the Crag deposits.

The resemblance of the new species to *Trochocyathus meridionalis*, Duncan, of the Australian marine Upper Tertiaries below the horizon of the so-called Pliocene is remarkable; but it probably depends upon the descent of both forms from some unknown Jurassic or Cretaceous ancestor.

EXPLANATION OF PLATE XXVIII.

Fig. 1. Calice of *Trochocyathus anglicus*: nat. size.
2. The same, magnified.
3. Side view of the corallum.
4. The base, magnified.
5, 5*a*. The corallum of *Solenastræa Prestwichi*: nat. size.
6. The calice, greatly magnified.
7. The epitheca, magnified.
8. The endotheca, greatly magnified.

Discussion.

Mr. Prestwich inquired whether the fossil bore any resemblance to any of the French Eocene forms, and whether there was any possibility of its being derivative.

Prof. Duncan replied that the specimen was but little worn, and was therefore probably not *remanié*, though this point was not absolutely certain.

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2. *On the* Discovery *of* Palæolithic Implements *in* Association *with* Elephas primigenius *in the* Gravels *of the* Thames Valley *at* Acton. By Colonel A. Lane Fox, F.G.S.

The gravels and brick-earths of this part of the Thames valley have been classed by Mr. Prestwich † and Mr. Whitaker into two principal groups:—1st, the high-level gravels of Mr. Prestwich, occupying the summits of the hills above the valley; and, 2ndly, the valley-gravels, occupying the sides and bottom of the valley itself.

With respect to the former, or high-level gravels, some slight difference of opinion appears at one time to have existed between the two authorities whom I have quoted—Mr. Prestwich including the gravels upon Wimbledon, Wandsworth, and Clapham Commons amongst the high-level gravels, whilst Mr. Whitaker considers the gravels of Wandsworth and Clapham Commons to belong to the valley-gravels. He, indeed, if I understand rightly his memoir on Sheet 7 of the Geological Survey Map ‡, appears to think it possible that

* As I find that this species cannot be figured, as I expected, in the 'Memoirs of the Palæontographical Society,' I have inserted figures showing its form and characters on the plate illustrating the new species described in the present paper.

† The Ground beneath us, its Geological Phases and Changes. By Joseph Prestwich, F.R.S., F.G.S.

‡ Memoirs of the Geological Survey of Great Britain, Sheet 7 of the Map of the Geological Survey.

the whole of the high-level gravel of Mr. Prestwich may be nothing more than higher terraces of the valley-gravel.

To enable the reader to understand at a glance the positions of the gravels I am about to describe, I have drawn a map of this part of the Thames valley, with contour lines of 10-feet levels strongly marked. A portion only of this map is given in the accompanying illustration (fig. 1), showing the part of the valley between Acton and the Thames. The margin of the London Clay is here shown by a dark tint, that of the gravel by a light one, and, for the sake of clearness, no distinction is made between the gravel and brick-earth. The geology of this district is taken chiefly from Mr. Mylne's map*, the accuracy of which I had the means of verifying in several places. The heights in this and all other cases are taken from the Ordnance datum, viz. mean tide at Liverpool, which is $12\frac{1}{2}$ feet lower than the Trinity datum of Mr. Mylne's map.

The valley-gravels proper of this neighbourhood, which for our present purpose may be roughly, though not accurately, described as the gravels lying below the 100-feet level, have been divided by Mr. Whitaker into three terraces, which it may be advisable here to describe, viz.:—a high-terrace gravel, occupying the shoulders and sides of the valley at a height of from 50 to 90 and 100 feet above the datum; a mid terrace, from 20 to 30 feet high, in the bottom of the valley; and a low terrace, occupying the low ground in the salient bends of the river, at an average height of from 10 to 20 feet.

Commencing with the north side of the river, he traces the margin of the uppermost river-terrace, or *high terrace*, as it may be convenient to call it, in contradistinction to the *high-level* gravel of Mr. Prestwich—from Drum Lane, north of Brentford, passing a little below Gunnersbury to Acton and East Acton, where this terrace ends off; and the next, or mid terrace, runs up at Wormwood Scrubs as far as the London Clay.

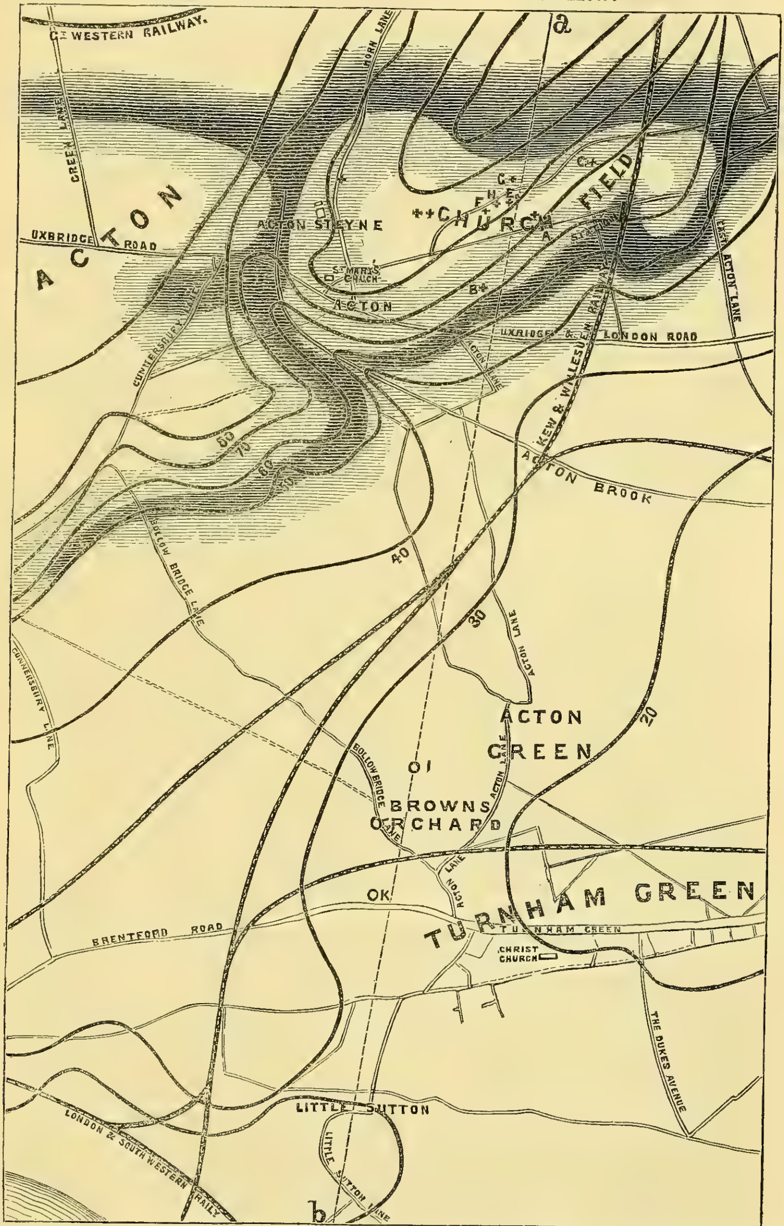
The northern boundary of the high-terrace gravel extends to beyond Hanwell on the west, passing by Ealing to Acton, where it is cut by a strip of the London Clay in the ravine of the Acton brook, dividing it from the isolated patch of high-terrace gravel to the eastward, which forms the particular subject of this paper. The average height of the northern limit of the high terrace is about 100 feet.

From Kensington to the Serpentine the high terrace is again found, rising at Campden Hill to the height of 129 feet, and extending beyond the Bayswater Road to the northward. Eastward of the Serpentine it rises again, extending from Piccadilly to Regent's Park, and from Paddington on the west to Finsbury on the east.

All the country to the north of this terrace, with the exception of a patch of gravel in the valley of the Brent, north of Twyford, and some other patches beyond the limits of the tract under consideration, consists of the London Clay; and strips of the London Clay also run round the patches of high-terrace gravel along the sides of the Thames valley, at an average height of 50 feet, dividing it from the

* Geological Map of the Contours of London and its Environs. By R. W. Mylne, C.E.

Fig. 1.—*Sketch Map of part of the Thames Valley, from Acton to near Chiswick and to the Thames at Kew.*



a b. Line of general section, p. 459. A–K. Sections opened. +. Flint implements. O. Animal remains. The dark tint shows the margin of the London Clay; the light tint that of the gravel.

mid-terrace gravel below. These strips of London Clay are seen at Hanwell, at Acton, and for upwards of three miles from Kensington to Temple Bar, always at an average level of 50 feet*. Along the sides of all the tributary streams, the Brent, the Acton stream, and the Serpentine, this strip of the London Clay is also found at about the same general level of 50 feet, dividing the high-terrace gravel into patches. The lower margin of the mid-terrace gravel runs from the river at Kew, by Chiswick House to Chiswick, where it again joins the river; all below this line, in the bend of the river, is the third, or low-terrace. In the next bend of the river to the eastward, the margin of the mid-terrace is not so well defined; but Mr. Whitaker has traced it along the river below Hammersmith to Fulham Church, and thence to Sandy End and Walham Green, and to the river at Cremorne. South of the river we have low-terrace at Ham, Petersham, Richmond, Kew, East Sheen, Barnes, Putney, Wandsworth, and Battersea. The mid-terrace is wanting, except between Barnes and Putney, to the north of the Barnes stream. A line of high-terrace gravel runs from Richmond Hill to East Sheen, commencing at the height of 50 feet. At Roehampton and Putney Heath, the high-terrace, if it be high-terrace, runs no lower than the 100-feet line, and rises to the height of 170 feet on Putney Heath. On Wandsworth and Clapham Commons the gravel rises to the height of 100 feet; this Clapham and Wandsworth gravel Mr. Prestwich formerly regarded as *high-level*, and considered it to form the same plain with that of Putney Heath. But both Mr. Prestwich and Mr. Whitaker, I believe, now consider the Wandsworth and Clapham to be high-terrace gravel, whilst that of Putney Heath and Wimbledon Common may be high-level gravel or a higher terrace of the river-gravel; certainly, if the level is to be taken as the criterion of classification, the Clapham and Wandsworth gravels would appear to correspond with the *high-terrace* gravel on the north side of the river, and to be somewhat lower than that of Wimbledon Common. As on the north, so on the south side of the river, the high-terrace gravels are divided from the mid- or low-terrace gravels by strips of the London Clay throughout nearly the whole of this district. Above Ham and Petersham the strip rises to a considerable height in Richmond Park. From Richmond to East Sheen, the upper margin of the strip, and the commencement of the high-terrace gravel, judging by Mr. Mylne's map, appears to be on the 50-feet line, whilst the mid-terrace gravel ends in about the 30-feet line. On the Roehampton and Putney-Heath hills the mid-terrace rises to the 50-feet line, while the upper-terrace gravel commences at about 100 feet, leaving the space between the 50- and 100-feet lines occupied by the strip of the London Clay †.

It seems to be doubtful whether or not this strip of clay runs along

* It is very probable that this strip will eventually be found to run further south along the valley of the Brent, and along the 50-feet line by Little Ealing, to join the strip at Acton; but this cannot now be determined.—A. L. F.

† This description is taken from Mr. Mylne's Map, which I have not had an opportunity of verifying in this place.

the steep slope which marks the boundary of the valley near Wandsworth and Battersea Rise*. It is seen along the valleys of all the tributary streams, which correspond in this respect with those on the north side of the river. This general description of the valley-gravels will, I trust, enable the reader to appreciate the position of the implement-bearing gravels under consideration.

My examination of the gravels in this district commenced in the year 1869, and has continued almost uninterruptedly ever since. A notice of the discovery of drift implements was communicated to the Meeting of the British Association at Exeter in that year. Several brick-pits were examined in the mid-terrace between Wormwood Scrubs, Shepherd's Bush, and Hammersmith; and the workmen had the appearance of flint flakes and implements explained to them by showing them specimens from other localities; rewards were also offered, to induce them to preserve any similar implements they might find during the excavations; but nothing of the sort was found in any of these pits. The brick-earth here lies from 10 to 12 feet thick upon the gravel; and, with a few exceptions, the cuttings did not extend lower than the brick-earth.

Passing westward along the Uxbridge road, I found that some excavations were being made for the foundations of houses in the high-terrace gravel in Churchfield, east of the village of Acton. The lay of the ground in this place corresponded so closely with that of the implement-bearing gravels of the Somme and the Ouse, that I determined to watch the diggings closely, and repeated my visits to this spot almost every day for some months. Reference to the section across the Thames valley from Acton to Richmond Park (fig. 5, p. 459), will show the position of this patch of gravel, resting upon the London Clay, a strip of which, as already mentioned, comes to the surface on the slope of the hill, dividing the high- from the mid-terrace gravel†. Near this strip of clay the superincumbent gravel does not exceed 6 and 7 feet, and it is much contorted. Seams of sand may be seen to turn up nearly on end, a good example of which was seen in Section A, in Arthur Terrace, on the line of the 60-feet level. Higher up it increases to 10 and 13 feet thick, as was shown in Section G, in Lorne Terrace, between the 80- and 90-feet lines; and to the westward, in Horne Lane, it was found in cutting for a sewer to be 18 feet thick. As a rule, the sections at the higher levels show the lay of the various seams of gravel and sand to be more even than in those parts which adjoin the outcrop of the clay, the seams thinning out gradually and horizontally in various directions. Between the 80- and 90-feet lines it was also noticed that in some places the gravel was overlain by a deposit of brick-earth, which passed down gradually and imperceptibly into fine sand. This was the case in Section F, in Chaucer

* Since writing this, Mr. Whitaker has informed me that he has traced it along this line.—A. L. F.

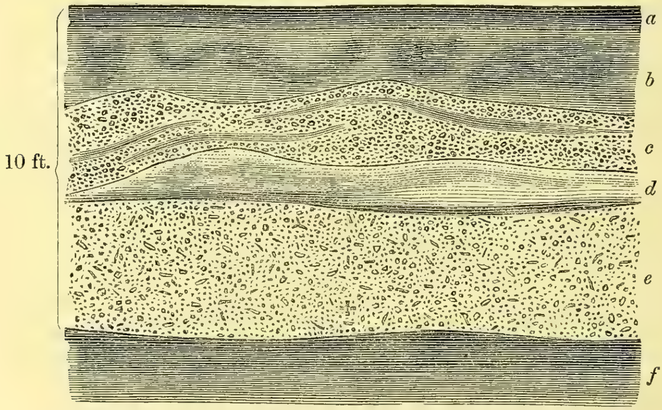
† This strip of clay is not marked in the recently published Geological Map, Sheet 7, but it is correctly given in Mr. Mylne's Map. I ascertained its existence by cuttings for sewers made in the lane to the eastward of the railway, and also in Grove Road; it consists of clay, with occasional irregularly shaped holes on the surface, filled with gravel.

Road. The gravels consisted of the usual subangular flints mixed with rounded quartz and quartzite pebbles, with occasional fragments of pudding-stone. No traces of river or other shells were discovered in this place. In the surface-soil were found some fragments of Romano-British pottery, the relics of comparatively modern occupation. To the eastward of the railway-station, in the foundations of East Acton Villas, on the 60-feet line, the ground appeared to have been disturbed. Some flakes and small scrapers were found in this place, all of surface type, and of a dark colour. Two chipped implements found here in the gravel are worthy of notice as being of surface type, although stained with the ferruginous colour of the gravel; one of these, of the celt-form, with an edge at the broad end, was found at a depth of about 4 feet; but whether it belonged to the gravel-deposit, or had worked in from the surface, I was unable to determine; it is, however, completely gravel-stained. To the westward of the station the ground rises, as seen by the contour-lines marking the 70-, 80-, and 90-feet levels.

In Alfred Road, Section B, the surface being 63 feet above the datum, a small oval-shaped implement was found at a depth of 7 feet, resting on the actual surface of the London Clay, and beneath an undisturbed seam of sand 6 inches thick. The surface of this implement is very much rolled; I saw it a few moments after it was taken out, and I have preserved a piece of the London Clay taken from immediately below the spot.

In Section C (fig. 2), surface 75 feet, is seen the position of some flakes and a flint, shaped like a rough scraper, found at a depth of

Fig. 2.—*Section C, in High-terrace Gravel at Hyde House, Shakespear Road.* Surface 75 feet.



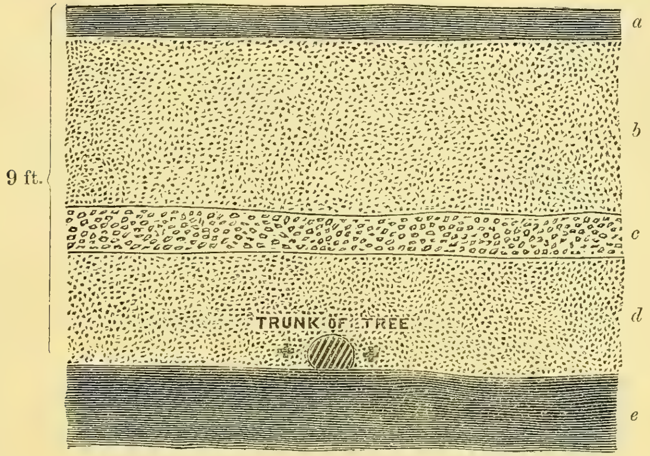
a. Surface soil, 6 in. *b.* Disturbed soil, 2–3 ft. *c.* Gravel and sand, ferruginous and irregular, with lines of black oxide of iron, 1–2½ ft. *d.* Clay-sand, blue, grey, yellow, and red, 0–18 in. *e.* Gravel and sand, with chips throughout, 4 ft. *f.* London Clay. + Position of flint implements.

9 to 10 feet, beneath irregular seams of blue, grey, yellow, and red clay-sand.

In Section D, west of Spencer Road, surface 75 feet, a layer of yellow sand, 2 feet 6 inches deep, with thin seams of red- and green-coloured sand, were seen between subangular gravel above and below.

Section E (fig. 3), in Lorne Terrace, surface 83 feet, shows the stratification at a spot where an unusual number of implements were dis-

Fig. 3.—*Section* E, *in High-terrace Gravel in Lorne Terrace, Myrtle Road.* Surface 83 feet.



a. Surface-soil, 6 in. *b.* Sand, 4 ft. 2 in. *c.* Gravel, 1 ft. *d.* Sand, 3 ft. *e.* London Clay.

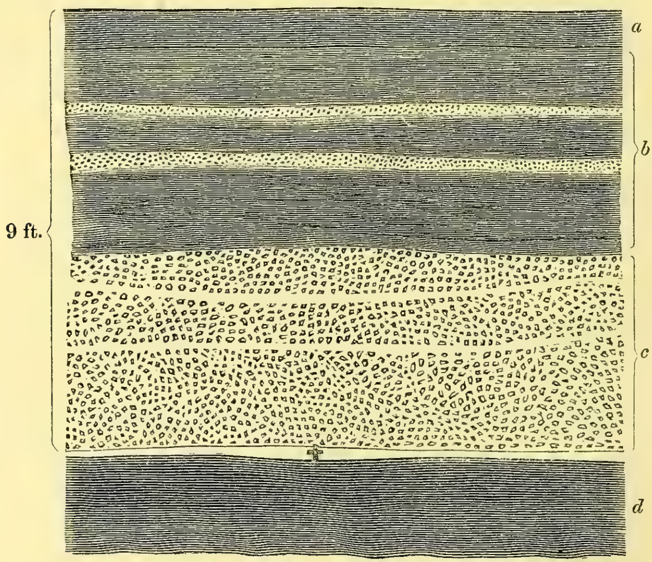
covered. Two of these, 4 inches long and $2\frac{1}{2}$ inches in width, pointed, and thick at the butt-end, were found close to a beam of wood, possibly the trunk of a tree, portions of which being submitted to Mr. Carruthers, were pronounced by him to be pine, " and probably *Pinus sylvestris*, Linn., the only indigenous species." This section, as will be seen, is composed chiefly of sand, with a strip of gravel 1 foot thick, at about 5 feet from the surface. Close to this section was also found a portion of the tooth of *Elephas primigenius* in the gravel, at a depth of 7 feet from the surface.

In Section F, in Chaucer Road, surface 82 feet, occurred the rhizome of a fern, the depth and position of which are worthy of notice; the deposits consisted of 6 inches surface-soil, 5 feet of brown brick-earth, passing gradually into fine yellow sand without stones, 1 foot of gravel, 2 feet of white sand, and the London Clay. Resting on this London Clay was found the piece of wood exhibited, which Mr. Carruthers has been so kind as to identify for me as the rhizome of one of our indigenous ferns, either the *Lastræa filix mas*, Linn., or the *Osmunda regalis*, Linn. One of the fronds, or a portion of the rhizome, rose in a serpentine direction to the seam of gravel 2 feet above, where it ended, and no trace of it was seen either in the gravel or the sand above. This section was seen by Mr. Flower and Mr. Searles Wood, the latter of whom suggested, in explanation of the position of the frond, that the rhizome of the fern must have been washed down by the stream, the heavier part resting on the bottom, and the frond rising towards the surface, in which position it must have become imbedded in volumes of sand. If this explanation is correct, it is evident that the flow of the river at that time must have been from west to east, viz. the direction of the present river. I leave it, however, for botanists to determine whether it may be possible that the rhizome of a fern of the surface-period may, by natural growth, have descended to so great a depth as 8 feet 6 inches from the surface.

Section G, at the top of Lorne Terrace, surface 83 feet, furnished the largest and best-formed implement discovered in this place. It is triangular, 8 inches long and 4 inches at the base; the natural surface of the flint is left at the butt-end. It was found beneath several deposits of sand, gravel, and brick-earth, at a depth of 13 feet 6 inches from the surface. The upper surface of the London Clay was here seen to slope gently upward towards the north.

Section H (fig. 4), shows the position of a number of flakes remark-

Fig. 4.—*Section* H, *in High-terrace Gravel north of Chaucer Road.* Surface 82 feet.



a. Surface soil, 6 in. *b.* Brick-earth with seams of white sand, 4 ft. *c.* Gravel with seams of white sandy clay, 4 ft. 6 in. *d.* London Clay.

able for the sharpness of their edges, all the others being blunted by contact with the other stones of the gravel. These were found in seams of white sandy clay, 9 feet from the surface, beneath deposits of gravel and brick-earth: the position of these flakes is of interest, on account of the edges of the whole of them being as sharp as when they were flaked off from their cores, proving that, whilst the majority of the flakes and implements in this place were carried down by the water, and rolled in the gravel, especially that referred to in Section B, these, on the contrary, must have been flaked off on the spot, and dropped into the soft sandy bottom of the river in this place, after which the deposits of gravel and brick-earth must have accumulated over them. Although I did not myself discover these flakes *in situ*, I satisfied myself of the correctness of the accounts given me by finding some of these sharp flakes in the excavated material with the soft, sandy, clay-deposit adhering to them. [Some of these were exhibited.]

At Mill Hill, on the other side of the ravine of the Acton brook, about half a mile to the westward, a very large flake was found in a seam of sand, 7 feet 3 inches from the surface, beneath stratified gravel interspersed with seams of yellow sand, the surface being 80 feet above the datum.

At Ealing Dean, two miles to the westward of Acton, in some gravel excavated for the construction of a sewer, the surface being 92 feet above the datum, I found two implements, one of which is an exceedingly fine specimen; it has a slender point, and is 5 inches in length and $2\frac{3}{4}$ broad, rounded at the butt-end. It is worthy of notice that, although I watched this place for some months, examining the cuttings in the gravel for the foundations of houses along the very same piece of road in which the implements were found, and although the workmen were expressly instructed what to look for, I never afterwards found so much as a single flake in this gravel. Upon inquiry, I found that the cuttings for the sewer were carried much deeper than the foundations of the houses; and the implements must therefore have been brought up from the very bottom of the gravel-bed, thus confirming in a remarkable manner the experience derived not only from Acton, but from other similar deposits of drift-gravel, in which the implements are all found to lie almost invariably at the bottom of the gravel. I was particular in examining into this question, because I am aware that there is a natural tendency amongst workmen to say that what they find is "right down at the very bottom;" as, however, the cuttings at Acton were made in steps, and the several levels were in most cases excavated upon different days, it was easy to test the truth of their statements; and I found that in every instance the implements came out of the lowest stratum of the gravel. Here the largest flint stones lie, and with them the implements, mostly of the dimensions of the larger stones, so that it was common for the more experienced workmen to say that they should find no implements till they got down into the coarse gravel; the smaller flakes, however, were not so invariably at the bottom.

To the north of the Great Western Railway, between Hanwell and

Ealing, some extensive cuttings in the gravel produced no trace of flakes or implements.

In all, about 22 implements and 160 flakes were discovered in the gravels at Acton and Ealing, the implements being far less numerous than in the similar deposits of the Somme or the Ouse. The forms of the implements vary between the oval and the pear-shape; and there is no evidence of the greater antiquity of either. Of these forms, nearly all were rounded, and left with the natural surface of the flint at the butt-end, only one having been found at Acton roughly chipped to an edge at the end. This is exclusive of the surface-type implement already mentioned as having been found to the east of the Station. The forms of the implements appear to have been determined by those of the stones out of which they were fabricated, an oval stone producing an oval implement, and a long stone a long implement. Most of the implements are of small size; and those found in Section F, being the commonest, might perhaps be selected as the Acton type. One implement, found by me in this gravel, is remarkable for being entirely untouched on one side, and roughly chipped on the other, showing that the fabricator selected a suitable pointed stone for his purpose, and, having one side prepared for him by nature, devoted his whole attention to the trimming of the other. Another implement was found in a rudimentary stage of manufacture, having only one side formed, by blows delivered all in one direction, when the fabricator abandoned it. [Two well-formed cores were exhibited, one of which was from Mill Hill.] The flakes, as a rule, are more abundant, smaller, and finer than is customary in the drift; some of these might be taken for surface-flakes; they are no doubt peculiar to the drift of this locality.

The long, sharp, thin flake, $5\frac{1}{2}$ inches in length, $\frac{1}{4}$ thick, and $\frac{3}{4}$ broad, found in the seam of soft sandy clay, in the position represented in the diagram, Section H, is, I believe, almost a unique specimen of drift manufacture, and suggests the possibility of many of the other flakes having been originally of more perfect construction before they became rolled and fractured in the gravel. Two or three specimens are bevelled at the end, as in the form of scrapers. Some of the implements were found by myself in gravel laid on roads, and excavated from spots the particular position of which could be ascertained. In all cases where sections are given, I took particular care to test the accuracy of the statements of the workmen as to the exact positions of the implements, and I have no doubt of their correctness in each case. Shortly after I commenced my visits to Acton, some rather ingenious attempts at forgery were foisted upon me, by chipping, varnishing, and, when dry, burying the flints thus prepared in the ground; but upon my pointing out at once to the workmen the precise manner in which each chip had been made, the recent character of the whole, the varnishing, the burying, and the economy of time and labour which might be effected by looking for the real implements when at work in the gravel, instead of wasting so much time over very imperfect imitations, they at once saw that it was impossible to deceive me, and I never afterwards found any attempt made to impose upon me. With respect to the animal-remains discovered in the high terrace, it was found that the surface-soil contained so many bones of recent animals which dropped down into the cuttings, that it was difficult to distinguish them from any that might be found in the gravel. The whole were therefore submitted to Mr. Busk, who has kindly undertaken to identify them, and whose report upon them will be read to the Meeting. (See p. 465.) The position of one tooth of *Elephas primigenius* may, however, I think, be regarded as fixed; it was found in the gravel, near Section H, in Lorne Terrace, at a depth of 7 feet. I did not see it taken out of the gravel; but it was handed to me shortly after it was discovered; and I have no reason to suppose, nor do I think there is any likelihood of its having been brought to this place from any other deposit of gravel. The nearest gravel-pit then being worked was a mile and a half distant; the bones of that gravel-pit were being collected for me by other workmen at the time; and there could be no object in transferring this bone from one pit to another when they knew that they would receive the same remuneration, from whichever pit it came. This, however, to the best of my belief, is the first tooth of *Elephas primigenius* which has been found in the high-terrace gravel. The mid terrace is prolific in animal-remains, as has been already shown by the researches of Professor Morris.

I now turn to the Mid-terrace gravel. About a mile and a half south of the Church field at Acton, in a place called Brown's Orchard, between Acton Green and the Brentford Road, some excavations were being made to obtain gravel. The position of this spot, with reference

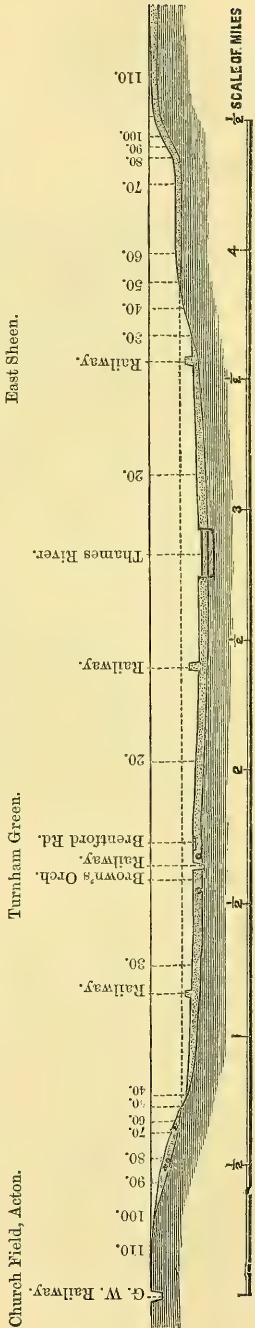
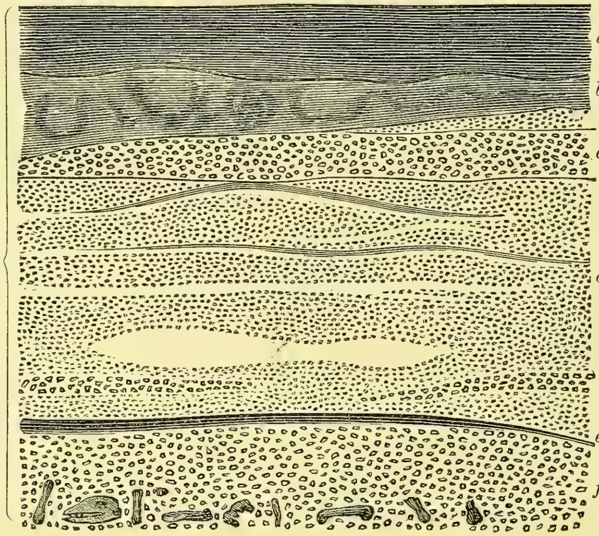


Fig. 5.—*Section across the Thames Valley from Acton to Richmond Park.* (Vertical scale 10 times the horizontal.)

to the Acton gravels, is seen in the cross section of the valley which passes through both places (fig. 5). The outcrop of the London Clay is here seen intervening between the two localities, separating the high from the mid terrace. The surface in Brown's Orchard is 24 feet; the stratification of the deposits is shown in Section I (fig. 6),

Fig. 6.—*Section* I, *in Mid-terrace Gravel, in Brown's Orchard, Acton Green.* Surface 24 feet.



a. Surface soid, 1 ft. 6 in. to 2 ft. *b.* Mixed earth, 6 in. to 2 ft. *c.* Gravel, 6 in. to 1 ft. 3 in. *d.* Sand with seams of red and white sandy clay, 8 ft. *e.* Black seam. *f.* Gravel with bones. This cutting extended to within a foot or two of the London Clay.

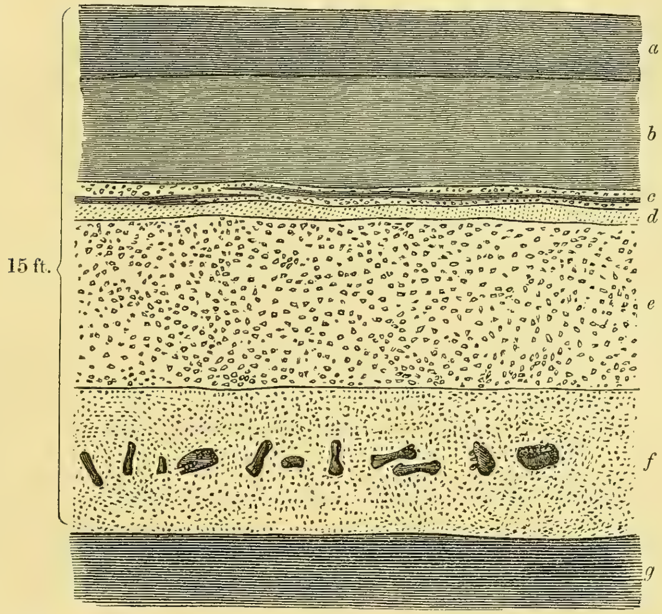
consisting of:—Surface-soil, 1 foot 6 inches to 2 feet; mixed earth, 6 inches to 2 feet; gravel, 6 inches to 1 foot; 8 feet of sand, with irregular seams of red and white sandy clay; a black seam of oxide of iron or manganese; 2 feet of gravel; and at the bottom of all, in close proximity to the London Clay (which, however, was not attained in this section on account of the quantity of water lying upon it), a thick layer of animal-remains, consisting of a variety of extinct animals, mixed together, and lying invariably at a level 12 to 13 feet from the surface; the names of these, which through the kindness of Mr. Busk I am enabled to give, consist of:—

1. Rhinoceros hemitœchus.
2. Equus caballus.
3. Hippopotamus major.
4. Bos taurus.
5. Bison priscus?
6. Cervus clactoniensis, *Falc.*
7. —— elaphus.
8. —— tarandus.
9. Ursus ferox priscus.
10. Elephas primigenius.

A detailed account of these will be given by Mr. Busk.

About 200 yards to the westward of this place, in Chiswick Road, on the other side of the Kensington and Richmond railway, and between it and the Brentford Road, another cutting for the foundation of a house showed the stratification represented in Section K (fig. 7),

Fig. 7.—*Section K, in Mid-terrace Gravel, in Chiswick Row, Turnham Green Road.* Surface 29 feet.



a. Surface soil, 2 ft. *b.* Brick-earth, 2 ft. 9 in.–3 ft. *c.* Clay and gravel, 6 in. *d.* Sand, 6 in. *e.* Gravel, 4 ft. 6 in. *f.* Sand with rounded and angular pebbles and bones. *g.* London Clay.

consisting of:—Surface-soil, 2 feet; brick-earth, 2 ft. 9 in. to 3 feet; seams of clay and sand, 1 foot; gravel, $4\frac{1}{2}$ feet; and $4\frac{1}{2}$ feet of sand with rounded and angular pebbles; and the London Clay at 15 feet; close to which, in the sand, at about a foot from the bottom, animal-remains were also found, as in Brown's Orchard. This was, I believe, some little distance to the eastward of the spot examined by Professor Morris, and described by him in the 'Journal of the Geological Society,' vol vi. Reference to the contours in the map will show that this ground is on a slight rise in the mid terrace, forming the watershed between the Brent and the Acton brook, tributaries of the Thames. Throughout this district, over probably more than half a square mile in extent, wherever the London Clay is reached, animal-remains in great abundance are found above it, and always, I believe, in close proximity to the clay. Careful search was made here, as in the high terrace, for flint implements; and as a proof that the total absence of human relics did not arise from any neglect in looking for them, I may mention that one of my most experienced men, who, on account of his numerous finds in the high terrace I called my flint-finder, was afterwards employed in Brown's Orchard; and although he laid down with his own hands upwards of three miles of gravel upon roads, and the same inducements were offered him as on the former occasion, he never found in this gravel so much as a single flake or chip which could be ascribed to the hand of man. This circumstance, tallying as it does with the result of my previous examination of the mid terrace, as before mentioned, near Hammersmith, is worthy of record. It would be unsafe to build an hypothesis upon negative evidence of this kind; but the gravel-excavations for the New Law Courts in the Strand, where the surface is about 40 feet above the Ordnance datum, and which is consequently on the level of the mid terrace, were found by Mr. Price, who examined them carefully from time to time, to be totally devoid of worked flints. The historical drift-implement of Gray's Inn Lane must have been found between the 60- and 70-feet line, and consequently on the level of the high terrace; and the flint found by Mr. Evans at Highbury was at a much higher level. It may, I think, be stated as a fact, that no flint of the drift-type in this region has hitherto been found below the 50-feet line, except in the bed of the Thames itself. From the Thames I have obtained one implement of drift-type; and Mr. Sparrow Simpson is in possession of a remarkably fine specimen, also from the bed of the Thames.

On the south side of the river my researches have been less complete than on the north side; I, however, examined the gravel-pits of the high terrace at East Sheen. The workmen had already been put on the look-out for implements by previous searchers, but, up to the time I visited the spot, had found nothing. In the high-terrace gravel at Wandsworth and Battersea Rise, after a fruitless search in several gravel-pits, and after carefully walking over some miles of gravel laid upon roads, I at last discovered one implement, together with a flake, lying on a heap of gravel at the junction of Gray-shot Road and the Wandsworth Road upon Battersea Rise. I made many inquiries to ascertain the exact position from which this gravel was obtained; I was informed by a workman that it came from an open gravel-pit within a few yards of the spot. The surface at this pit was between the 50- and 60-feet line, and it occupies exactly the same position above the strip of London Clay as the implement-bearing gravel at Acton. It is extremely probable that it came from this pit; but it is certain that it came from some part of Battersea Rise; for the quantity of gravel which is obtained from pits in this neighbourhood makes it extremely improbable that this particular heap should have been imported from elsewhere. Moreover the absence of implements in the gravel of this hill generally, makes it the more probable that it came from the particular pit near which it was found, as this pit had been but little worked; and it is possible, therefore, that the heap in question may have been the firstfruits of an implement-bearing bed, which may turn out to be more productive hereafter.

It may perhaps be expected that, in concluding this paper, I should offer some conjectures of my own upon the unsettled question of the age and mode of deposition of the river-gravels. I confess, however, that the evidence which I have been able to collect does not appear to me to warrant any fresh hypothesis. There are, however, one or two fragments of archæological evidence, proving the great antiquity of the present bed of the Thames, which appear to me to have some bearing on the question of the erosion of the Thames valley. Near the town of Dorchester, at the junction of the Isis with the Thame stream, are the ancient earthworks known as the Dorchester Dykes, attention to which has unfortunately been drawn by their recent destruction. These works consist of a nearly straight line of entrenchment in the bottom of the valley, running from the Isis on one side to the Thame stream on the other, and enclosing the flat salient promontory formed by the bend of the river. The flanks of the entrenchment rest upon the stream on both sides. The requirements of defence demanded that they should rest upon the stream at the time they were constructed; there is evidence, therefore, that the river must have run in its present course through the flat bottom of the valley at that time. Nor could the conditions of its flow have been materially different from what they are at present; for the river still floods a considerable portion of the enclosed space, and, if it had habitually risen only a few feet higher, it would have rendered the spot unsuitable as the site of an encampment. Now the associated relics prove that this entrenchment is the work of pre-Roman times. All the works of art discovered within the area of the entrenchment are of flint or bronze; and notwithstanding the existence of a Roman station at Dorchester close by, nothing Roman is found in this place. We have evidence, therefore that the Thames ran in its present course, and under nearly the same conditions as at present, ever since the bronze period of England; and how much longer, we cannot tell. But we have facts of the same kind within the district represented upon our map*. From Ham to Petersham the river runs northward, by Richmond to Kew, where it bends to the south, running to East Sheen, and then turns again northward, running by Barnes to Hammersmith; again turning to the south, it flows by Putney and Wandsworth, turning north again, in the direction of Battersea and Chelsea, thus making four bends between Ham and Chelsea in the comparatively flat bottom of the valley. Throughout the whole extent of this winding course, almost wherever the dredging machine is put into operation, relics of the bronze and stone age are turned up at various depths, extending to 10 feet below the existing bed of the river. Mr. T. Layton, F.S.A., of Kew, to whom I am indebted for information on this subject, has collected nearly one hundred specimens of the prehistoric age, many of which are bronze leaf-shaped swords, together with a number of stone and bronze celts from different parts of the river.

* Referenee is here made to the larger map exhibited to the Meeting.

Near the mouth of the Brent, at Kew, piles may be seen beneath the water, marking, no doubt, the site of a river habitation, similar to those of the Swiss lakes; and at Barnes, in the opposite bend of the river, similar piles have been found, associated with a number of flint celts and dolichocephalic skulls of the form believed to have belonged to the earliest inhabitants of these islands. As these relics, to the best of my belief, are not found in the Thames valley elsewhere than in the existing bed of the Thames, it follows that the river must have flowed in the same meandering course for two thousand years, and in all probability for a much longer period, the bed of the river having actually *risen* during this period, as appears by the depth at which these ancient relics are found beneath the sedimentary deposits*. We are thus led to form an idea of the enormous time that would have been required to erode the whole valley by means of a river flowing under the same conditions as the present one, to effect which it would have been necessary for the river not only to have shifted its bed over every portion of the present surface of the valley, but to have done the same thing repeatedly at different levels, over an extent of country which, as shown by the section, must, on the 100-feet line, have exceeded four miles and a half. This theory of the gradual erosion of the valley by means of a river of the same size as the present one, however, appears to have been abandoned by some of the best authorities.

The presence of large tracts of brick-earth overlying the gravel, argues, as I venture to think, the existence of large volumes of water at the time they were deposited. Then to what cause are we to attribute the strips of the London Clay laid bare on the sides of the valley, and of the tributary streams, at the average level of 50 feet? Obviously to denudation of some kind. Why, then, is this denudation not continued along the sides of the same streams into the mid terrace and down to the present river? The mid terrace, instead of being broken into patches by denudation, like the high terrace, is continuous, following the sinuosities of the valley up to the limit of the 50-feet line, or thereabouts. I venture to suggest, though not without diffidence, that a body of water, occupying the whole valley up to the 50-feet line, would account for the phenomena presented. The denudation of the patches of the high terrace would be caused by the drainage *into* this body of water. The mid-terrace gravel would be the result, in a great measure, of accumulations *beneath* the surface of the water. If this hypothesis were admitted, the implements of the high terrace must belong to a period anterior to that at which the river or lake stood at this level; and there is no reason, therefore, why they should not be found in the gravels still higher above the river†.

The presence of these implements in the high terrace, their absence, so far as our researches go, in the mid terrace, and their reappear-

* The stone implements, I understand from Mr. Layton, are found lower than the bronze.

† I may here notice that no shells of any kind were found in the sands, although they were carefully looked for

ance again in the present bed of the Thames—the abundance of animal-remains in the mid terrace, and their great rarity, if not absence, in the high terrace—and the invariable occurrence of both implements and animal-remains in the *lowest strata* of the gravel immediately adjoining the London Clay, are facts which demand an explanation of some kind. It is rather with the view of submitting these points to the judgment of geologists, than of attempting to explain them myself, that I have prepared the accompanying maps and sections with as much attention as possible to detail, and in the hope that the slight addition thus afforded to our knowledge of the distribution of the drift-implements in the Thames valley may not prove unacceptable to the Geological Society.

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3. *On the* Animal-remains *found by* Colonel Lane Fox *in the* High- *and* Low-terrace Gravels *at* Acton *and* Turnham Green. By Geo. Busk, F.R.S., F.G.S., &c.

[Plate XXIX.]

I. High-terrace Gravel.

The animal-remains from the High-terrace Gravel belong to *Bos*, *Ovis*, *Equus** and *Elephas*?

1. *Bos*.—The bovine remains comprise by far the greater part of the specimens collected at this level. They are all in a comparatively recent condition, though some appear to have been more exposed to atmospheric influence previous to interment than others. Most of the bones also exhibit marks of cutting or chopping with a sharp metallic implement; and none have been exposed to fire. Some few present faint indications of manganous deposit, in the form of minute specks; but none, with one exception, can be called dendritic, nor do any of them adhere to the tongue, or but very slightly so. In fact, they may nearly all be regarded as of modern origin, and as belonging to the common ox of rather small size. A perfect metacarpal measures 8 inches in length. Amongst the bovine remains is what appears to be a portion of the metacarpal of a calf.

2. *Ovis*.—The ovine relics are very few in number, and all modern.

3. *Equus*.—Two specimens only belonging to the horse occur in the High-level collection, viz. a left lower molar and a portion of the right scapula, including the glenoid cavity. Both these specimens are dendritic; and the fragment of the scapula is highly ferruginous and much decomposed, apparently from subaerial exposure, so that the surface scales off in thin laminæ. From their condition, these bones would seem to belong to a different period than

* As a curious instance of the way in which animal-remains may become mixed together, it may be mentioned that the nearly entire pelvis of an Emu was found, as it is stated, in "brick-earth at Acton, close to the south of the High-level terrace Gravel, at a depth of about $2\frac{1}{2}$ feet from the surface," the truth being that it was found in garden-mould at that depth.

those of the ox and sheep, or, at any rate, to have been subjected to different conditions as regards exposure &c.

4. *Incerta.*—The other remains from this level are eighteen or twenty broken and rolled fragments of long and flat bones of some large animal or animals, not improbably Elephant, Rhinoceros, or Hippopotamus. Most of them are too imperfect to allow of correct determination; and all are extremely friable, loaded with manganous oxide, and apparently retain very little animal matter, since they neither blacken nor smell when burnt. As they are, as above said, much rolled, it may be presumed that they may have formed part of a previous deposit. But amongst these remains is a large portion of an elephant's molar, which will be referred to subsequently.

II. Mid-terrace Gravel.

The remains from the Mid-terrace Gravel, with one or two exceptions, all present characters of great antiquity. They are all highly dendritic, and adhere strongly to the tongue. They vary, however, a good deal in colour, many being white and chalky, except where stained with manganous oxide, whilst others are highly ferruginous. They present no evidence of their having been water-worn or rolled; and from the circumstance that several portions of the same skeleton have occurred at no great distance apart, it would seem probable that the carcasses of the animals had been deposited more or less entire not very far from the locality in which the bones were found, viz. a bight of the ancient river.

The bones of decidedly recent origin (five or six in number) belong to the Horse (of which a nearly entire skeleton was found in one of the pits) and Ox, the latter species being represented by the proximal end of a *humerus*, whose shaft has been chopped across; most probably an old marrow-bone.

The really fossil bones belong to the following species:—

I. Perissodactyla.
- 1. *Rhinoceros hemitœchus.*
- 2. *Equus caballus.*

II. Artiodactyla.
- 3. *Hippopotamus major.*
- 4. *Bos taurus* (*primigenius*).
- 5. *Bison priscus.*
- 6. *Cervus clactoniensis* (*Browni*).
- 7. —— *elaphus.*
- 8. —— *tarandus.*

III. Carnivora.
- 9. *Ursus ferox priscus*? (*U. priscus*).

IV. Proboscidea.
- 10. *Elephas primigenius.*

1. *Rhinoceros hemitœchus.*—The only distinguishable relic of *Rhinoceros* is a nearly entire left ulna, whose form and dimensions agree precisely with those of *Rhinoceros hemitœchus* from the Ilford gravel, of

which species such abundant remains are to be seen in the collection of Sir Antonio Brady. This bone appears to have been met with quite at the bottom of the Thames valley, at a height of from 10 to 20 feet only above high-water mark, and at a depth of 8 feet from the surface, beneath a layer of fine yellow sand.

2. *Equus caballus.*—The only indubitable ancient vestige of the horse in this deposit is a solitary lower molar, which is undistinguishable from that of the existing form.

3. *Hippopotamus major.*—The remains of the *Hippopotamus* are rather numerous, belonging, as it would seem, to individuals of at least two (or perhaps three) different ages—one quite mature, one at the age at which the proximal epiphysis of the tibia is still ununited and the epiphyses of the metatarsals still show the line of junction, and one apparently a much younger animal, probably only a few months old. Though most of these bones are much broken, they appear but very little water-worn or rolled. As they constitute an interesting part of the collection, I propose to give a somewhat detailed account of them. They consist of:—

1. The occipital crest of a fully mature animal. It is about the same size as that of the existing species, as shown in the skeleton in the College of Surgeons, but differs from it in the much greater depth and smoothness of the anterior concavities. *Found in Brown's orchard, Mid-terrace Gravel, in June* 1870.

2. Fragments of the right and left scapulæ. Found in the same locality.

3. Several large fragments of the left os innominatum, including part of the sacro-iliac articular surface. As the fractured edges all appear to be recent, it is not improbable that further search would have led to the discovery of the entire bone.

4. The proximal epiphysis of the left tibia, wanting part of the external articular facet, but otherwise entire and little worn.

5. The left fourth metatarsal of a fully mature animal (Pl. XXIX, fig. 1), very nearly perfect, as it only wants the hinder apophysis. The bone is 5·5 inches long, and its least circumference 5·1, giving a perimetral index of ·927.

6. The right fourth metatarsal of a young animal (fig. 2), inasmuch as the line of junction of the epiphysis is indicated by a deep groove. The bone is 5·75 inches long, and its least circumference 4·2, giving a perimetral index of ·730.

7. The left frontal of apparently a very young animal, to judge from the size and porous structure of the bone, which is 3″·4 measured along the mesial side, and 2″·9 transversely*. The bone is nearly entire, and, notwithstanding its porous nature, is very little worn; so that the depression for the reception of the nasal is sharply defined, and the cerebral sulci on the inner surface remain quite distinct.

This specimen suffices to show, did any doubt exist on the matter,

* The frontal bones in a young hippopotamus born in the Zoological Gardens, and which died a few days after birth, measured in the same directions 1·9 and 2·3.

that *Hippopotamus major* bred in this country, and was not a mere summer visitant, as some have formerly supposed.

The extraordinary difference, in proportions and also in form, between the two metatarsals above noticed is well worthy of remark; for it is so great that, under other circumstances, it might fairly have been assumed that they belonged to distinct species.

The comparative slenderness of the younger bone (fig. 2, Pl. XXIX.), which in that respect stands to the other as 730 to 927, at once strikes the eye, whilst in the form of the shaft also they differ very considerably. In the older bone the anterior and posterior surfaces are hollowed or concave from side to side, particularly the latter, the hollow being bounded on either side by a prominent ridge; whilst in the younger bone both surfaces are convex, and there is, on the posterior surface only, a very faint ridge on the tibial border. The facet, however, by which the fourth metatarsal articulates with the third is of the same form and shape in each. There is no appearance of a bursal (?) facet on the extremity of the hinder apophysis, such as may be seen in most metatarsals of the recent *Hippopotamus*. Comparison of the figures will serve to show at once the extraordinary difference between these two metacarpals, and to indicate also how closely the younger of the two approaches the proportions of the same bone in *Hipp. amphibius* *.

It is not easy to assign the age of the individual to whom the frontal bone belonged; from its size, however, and porous structure, it would seem impossible that it could have formed part of the skeleton of the same individual as that which afforded the detached tibial epiphysis and probably also the slenderer metatarsal bone, and which must have nearly reached its full stature, the epiphysis in question measuring very nearly 5 inches in the antero-posterior direction, or from the point of the tuberosity to the hinder border of the inner condyloid facet.

4. *Bos.*—The bovine remains are very numerous, most of them of very large size, and obviously of great antiquity. In all probability they belong to *Bos primigenius*; but as they vary somewhat in dimensions and character, some may perhaps be referred to *Bison priscus*.

6. *Cervus.*—The next most numerous remains are:—*a.* Those of a very large species of *Cervus*, apparently equal in size to *C. canadensis*, and with the brow-antler arising immediately above the burr, or even from it, and turning downwards, as in the Clacton specimens, to which form I should be inclined to refer the larger cervine remains and antlers (*C. clactoniensis*, Falc., *C. Browni*, B. Dawk.). *b.* A few relics, however, of a smaller deer, no doubt *C. elaphus*, also occur, amongst which are a perfect astragalus and a nearly perfect calcaneum of opposite feet, whence, perhaps, it may be surmised

* In the skeleton of *Hipp. amphibius* in the Museum of the Royal College of Surgeons, the articular surfaces between the third and fourth metatarsals is prolonged along the whole length of the hinder apophysis. But in other instances this condition was not found to exist, nor have I met with it in any case of fossil hippopotamus.

that the carcass to which they belonged had not been brought any very great distance. *c.* One large portion of an antler, undoubtedly of *C. tarandus*, indicates the coexistence of that species; but as no other portions of the skeleton have been discovered, this specimen may have been brought down by the river from some distance.

9. *Ursus.*—The only bone belonging to the Carnivora is the left fifth metacarpal of a Bear of large size. The bone, which is quite entire, is 3″·9 long, its least circumference 2″·5 (perimetral index ·641). It would seem to belong to *U. ferox priscus*, as it is too slender for *U. spelæus*, and altogether too large for *U. arctos*. No teeth or other portions of the skeleton of *Ursus* have as yet been met with; still, as the present specimen is entire and unworn, it would seem that it could not have been carried very far.

10. *Elephas primigenius.*—The Mammoth is distinctly represented by portions of three upper molars and a fragment of a dorsal spine. But besides these there are several other fragments of bone which, from their thickness and texture, not improbably belong to this species.

1. The fragment of dorsal spine betokens an individual of large size. It is recently fractured at one end; but the other is much rounded by attrition. The specimen was found in the Mid-terrace Gravel at Acton Green.

2. A second specimen, also found at Acton Green, in the Mid-terrace Gravel, at a depth of 12 feet, in March 1870, is somewhat remarkable on account of its mineral condition, which is very different from that of the two other teeth to be described below. The present is a fragment, measuring 3·8 × 2·4, of a right lower *m* 1. It presents the worn surfaces of six plates and of half a plate at each end. Five entire plates occupy a length of 2″·5; consequently they are of unusual thickness for *E. primigenius*, although, from the form and thickness of the enamel ridges, there can be little or no doubt of the tooth belonging to that species. Under other circumstances, however, it might equally belong to *E. indicus*. The tooth is very heavy and dense and hard, the dentine quite black, and the osteine deeply mottled with manganous oxide.

3. Of the other two teeth, one is marked as having been found in the High-terrace Gravel at Acton, as recorded in Col. Lane Fox's paper; and although in colour and general condition it exactly resembles the tooth next to be noticed, which was obtained from the Mid-terrace Gravel at Turnham Green, there is nothing, from this circumstance alone, absolutely opposed to its having been derived from the High-terrace Gravel, which in general characters does not appear to differ very materially from the Mid-terrace deposit. Nevertheless it will perhaps be more prudent not to assume positively that there has been no confusion in the account given to Col. Lane Fox by the finders.

The specimen is a much-broken portion of an upper molar of the right side, about 5″·5 long, presenting the remains of twelve or thirteen plates, which are, so far as can be judged, unworn. They are also very easily separable, and incomplete at the base. And as numerous portions of detached plates, in all probability belonging to this tooth, occur in the collection, I conclude that the specimen represents the last upper molar in a state of germ or nearly so.

4. The third specimen is a nearly perfect upper molar, entirely in the germ-state. It is about 3″ long by 2″·2 wide, and exhibits eight plates, and apparently had at least one or two more at the anterior end. It would therefore appear to be an $\overline{m.m\ 4}$, or $\overline{m\ 1}$, although, if so, it is of rather unusual width.

DESCRIPTION OF PLATE XXIX.

Figs. 1 and 2. Two fourth metatarsals of *Hippopotamus major*.

Discussion.

Mr. Prestwich complimented Col. Lane Fox on the exactness and completeness of his description of the classical district which he had investigated, in which mammalian bones had been found and described by Mr. Trimmer so early as 1815. In that case Hippopotamus-remains, very fresh and unworn, had also been discovered. Prof. Morris had also described a deposit near Brentford in which numerous remains of Reindeer were present, showing how variable was the distribution of mammalian remains even in a limited area, and how unsafe it was to base theories upon merely negative evidence. It was to be hoped that other investigators would extend similar discoveries to other parts of the valley of the Thames.

Mr. Godwin-Austen did not think that the presence of the young Hippopotamus was absolutely conclusive of its having been born in this country. With regard to the presence of remains of Reindeer and Hippopotamus in the same beds, not only might there have been an overlapping of faunas such as has been pointed out by Sir Charles Lyell, but there might also be an intermingling of the included remains from two beds of different ages. He was not altogether satisfied with the evidence as to the coexistence of man with *Elephas primigenius*, nor as to the artificial character of some of the presumed implements. He did not attach any great importance to the merely fragmentary bones.

Mr. Evans maintained that the implements exhibited were of necessity artificial, and commented on the nature of the evidence as to the coexistence of man with the Pleistocene fauna. Under any circumstances the gravels containing the implements could only have been deposited at a time when the Thames valley had not been excavated to any thing like its present depth; and they were therefore of great antiquity. There was, moreover, a notable absence in them of a number of the animals usually found associated with Neolithic implements; and if man had not subsisted on the animals the remains of which were found associated with his handiworks in the gravels, it was a question on what food he had had to depend. The absence of implements in the low-level gravels seemed to him significant of a diminution in the number of the human beings who frequented the banks of the river.

1 2

E.M.B. ad nat. Lith. Maclure & Macdonald, imp.

METATARSALS OF HIPPOPOTAMUS.

Mr. Carruthers said that as the rhizome, whether it was that of *Aspidium* or *Osmunda*, was an aërial, and not a subterraneous rhizome, it must have been carried to its present position; and it consequently indicated, as Col. Lane Fox had pointed out, the direction of the stream.

Mr. Flower regarded Col. Lane Fox's memoir as of great interest, as affording an additional instance of that perfect similarity of these deposits, whether in France or England, which in places so wide apart might reasonably be taken to indicate a common origin. It was indeed generally assumed that these deposits were brought down by rivers; but this, according to his view, was by no means certain. Col. Lane Fox had described the valley as 4½ miles wide; but there was at Croydon, 12 miles distant, a deposit of gravel capped with loess, containing elephant-remains, and exactly resembling the Thames-valley gravels, and communicating with them. This evidently formed part of the Thames-valley system, whatever that system might be taken to be; and if so, he thought it incredible that the loess should have been distributed by river-action over an area 12 or 15 miles in width. In conclusion, he was quite content to adhere to the opinion held by the French geologists, and formerly by several of our own most able writers, that the distribution of these superficial drifts was in the first instance diluvial rather than fluvial.

Col. A. Lane Fox, in reply, pointed out the artificial character of the implements, and the manner in which the mammalian remains occurred. He thought that some part of the brick-earth of the lower terraces might have been deposited at the bottom of a lake.

Mr. Busk, in proof of the animal-remains not having been brought from a distance, showed that remains of the same animal were found in close proximity to each other.

Prof. Ramsay made some remarks on the undoubtedly artificial character of the implements, and on their position at the base of the gravels. The origin of the Thames valley he had already maintained to be of Postmiocene age; and though there was at present no evidence of man's existence at that time, it was still possible. Of the extreme antiquity of the human race there could, however, be no doubt.

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4. *On the* Evidence *for the* Ice-sheet *in* North Lancashire *and adjacent parts of* Yorkshire *and* Westmoreland. By R. H. Tiddeman, Esq., M.A. Oxon., F.G.S., of the Geological Survey of England and Wales.

[Communicated by permission of the Director General of the Geological Surveys of the United Kingdom.]

[Plate XXX.]

Introduction.

The materials on which the remarks are founded which I now have the honour of submitting to the Society, have been collected by me for several years past whilst carrying on the work of the Geological Survey. The process has been necessarily slow; for the direct evidences do not generally obtrude themselves upon one's notice, and they are so sparingly scattered over the ground, and so affected by the form of the ground and other local causes, that any generalization from a mere partial examination of the district would be worthless. It has been my privilege to go over the greater part of the area acre by acre; and although objects of more practical utility have been the chief aim of this examination, I have always been on the look-out for any records of the Glacial period which are graven on the rocks themselves. I believe that very few such which are exposed have escaped my notice; and those found I have endeavoured to register impartially, leaning as little as may be towards one theory or another.

I intend, first, very briefly to describe the physical features of the district.

The region lies between latitude 53° 38′ and 54° 18′, and extends from the great watershed of England on the east to Morecambe Bay and the Irish Sea on the west. To the N.N.W. are the Lake mountains, and to the south the plains of Cheshire and South Lancashire. The accompanying map (Pl. XXX.) will explain better than words the features of the country. It is on the scale of $\frac{1}{3}$ inch to a mile, and is coloured to represent elevations. The contours of one half of it have been reduced from the Ordnance 1-inch contoured maps, the remainder from the 6-inch scale. The levels which I have used are those of 200, 500, 1000, 1500, 2000 feet. The great watershed is traced in lozenge-shaped dots.

On the west, next the sea is a great plain, a continuation of that of South Lancashire and Cheshire. It consists chiefly of Trias and Permian much covered and almost entirely concealed by Glacial drift and alluvium. This all lies below the 200-feet contour, and is in some places more than 12 miles broad. Its extent is rudely represented by the main mass left white on the west margin of the map.

With the exception of a small portion in the north-west corner of the map forming the estuary of the river Kent, the rest of the district west of the watershed consists of the drainage-systems of the Ribble and the Lune. The whole of the Ribble-basin is contained in the district, and a great portion of that of the Lune. The main direction of these rivers is from the north-east.

The Ribble-basin is bounded on the south-east by a chain of moorlands running north-easterly from Chorley, called by Mr. Hull the Rossendale Anticlinal. They rise to heights of from 1000 to 1500 feet, one summit only attaining the latter elevation. Their southern flanks drain into the Irwell, and thence by Manchester into the Mersey. On the north of them is a long valley containing the valuable coal-field of Burnley and Blackburn. This country drains north by the rivers Calder and Darwen, which pass through narrow defiles in the long Pendle range of hills into the valley of the Ribble.

The Pendle chain of hills is a strongly marked feature in the district. It consists of the entire thickness of the Millstone-grit and Yoredale series, and runs with a tolerably straight course from near Chorley on the sea-side plain to and beyond the great watershed; its highest point is Pendle Hill, 1831 feet. The rocks of which it is formed dip, for the greater part of their course, at very high angles to the south-east. To this I shall again refer.

The Ribble runs along an anticlinal valley excavated in carboniferous shales and limestones, which, from the alternations of hard and soft rocks, crumble away quickly under denuding forces.

Between the Ribble and the Lune lies a great rudely circular patch of high moorlands intersected by small radiating valleys, which, as it has no general name, I will call for the purposes of this paper the Central Fells. It is about 18 miles in diameter, and consists of the Yoredale and Millstone Grits, dipping gently north. The highest point is Ward's Stone, 1836 feet, 5 feet higher than Pendle; but several of the Fells rise to nearly 1800 feet. Indeed, looking from the hill-summits, one cannot but be struck by the apparently uniform level to which all these Fell-tops rise, suggesting most vividly a very old "plain of marine denudation." The summits show here and there mounds of loosened rock in the last stages of disintegration. Sometimes scars of grit occur, but only where some valley-slope in close proximity has eaten into the foundation of the rock which forms it. Generally the tops are rounded and void of any sharp features, and for the most part clothed in peat-moss from 1 to 15 feet or more in thickness; and they form a wild bleak country, tenanted only by sheep and grouse, the plover and the curlew. North of this tract the grits of which it is composed dip beneath the comparatively low district of the Ingleton coal-field; it is between the 200- and 500-feet levels in the basin of the Lune. To the west of this is the Lune, running south-west by Lancaster; and again west, separated by a low tract, lies the estuary of the Kent.

The north-east corner of the map contains a high tract of country, constituting one of the principal parts of the Pennine chain of hills. On its south-east border lie the well-known hills of Ingleborough, Pennigent, and Fountains Fell, rising respectively to the heights of 2373, 2231, and 2191 feet above the sea; and on the north, Whernside 2414, Gragreth 2250, Widdale Fell 2203, &c. This high country is separated from that west and south-west by a broad valley, which runs along the Craven Faults. This may have been at some former time a continuous line of drainage, but is now crossed by the watersheds between the Lune and the Ribble and the latter and the Aire; and portions of it are now drained by all three of these rivers. It has been already mentioned that the general course of the Lune and Ribble is to the south-west; but the former, when running alongside, and the latter through, this high tract, have a southerly direction. The fact remains that over the greater part of this district these rivers and their tributaries, and consequently the valleys, run to the south-west.

I now propose, first, to give a description of the scratches found upon the solid rocks, distinguishing, where possible, between those which may have been the result of local glaciers and those which, from their position or other circumstances, must be memorials of the great Ice-sheet at the period of its maximum development.

I will then, secondly, give an account of other indications at the surfaces of the rocks which seem to point to the movement of ice over them.

Thirdly, I will endeavour to show the inferences to be derived from a study of the Till in connexion with the other phenomena; and

Lastly, the general conclusions as to the Ice-sheet to be derived from a study of this district, and the inferences which may be drawn by correlating the observed phenomena of this district with those of others surrounding it.

I. Ice-scratches.

The whole of the rocks of this country, wherever the Till or Lower Boulder-Clay now exists, or may reasonably be supposed to have not long been removed, show a *moutonnée* and usually striated surface. Wherever the rocks have been hard enough to resist the weather, or the overlying Till stiff enough to protect the scratches, they still remain. There is hardly a quarry or rock-exposure in the district where you have a hard line between the top of the rock and the overlying Till where you may not find scratches. Of course where you have soft shales or sandstones or rapid alternations of hard and soft rocks under the Till, the two are much confused and no such direct indications exist.

It is only where subsequent rain or river denudation in the valleys has removed the glacial surface of the ground, or high up on the Fells where no stiff drift has remained to act as a shield, that you cannot find *moutonnée* surfaces. Finding the ice-mouldings so general in places suited for their preservation, it is almost impossible to avoid the conclusion that the whole country has been at one time one vast ice-covered *roche moutonnée*.

In placing upon the map (Pl. XXX.) the observations which have been made on this subject, I have merely given the line of the direction of the travelling mass, and not the quarter from which in each case the ice may be supposed to have come. I have done this because I have been afraid lest I should appear by any personal bias to distort the facts and so affect the main question. I have preferred to lay before the Society the scratches, which do not admit of controversy, and leave them to be judges in each case of the probable direction in which the ice moved along those scratches.

I need scarcely say that the sign employed on the map does not indicate in each case the distance over which the scratches are seen, but the centre of each sign is the point at which the observation has been made. It must not be supposed that the absence of scratches in three corners of the mass indicates their non-existence, but merely that no observations have been made, those portions being beyond my district.

My thanks are due to my friend Mr. T. McK. Hughes for notice of several scratches in the extreme north of the map, and also for some in the neighbourhood of Ingleborough. I may state that throughout this district at each locality the striæ are tolerably regular and parallel. Some few do, of course, cross the others obliquely; but there is seldom any difficulty in seeing which is the main direction. Such slight and unsystematic deviations may easily have been made by stones falling into crevasses, which would not necessarily at first have their principal axis in the direction of the movement of the ice. Such rotation as would be produced in accommodating their axes to the direction of least resistance would cause any projecting points to form scratches oblique to those produced by stones which had already assumed that direction.

The Scratches of the Lune District.—There appears to be a greater harmony of arrangement along parallel curved lines here than in any other part of the district. It will be seen that near the north edge of the map, about Killington Common, they have a south-south-westerly direction; a few miles further south they are a little more westerly, whereas about Lancaster and south of Morecambe Bay they curve again to the south. It is not easy to describe the parallelism of curvature; but the map renders it at once apparent to the eye.

Now, can these be accounted for by a local glacier? Those on Killington Common are on one of the highest parts of the ridge between the valleys of the Lune and Kent, and run along its crest, not across it. They are about 600 feet above the adjoining valleys. Those further south are not on quite such high ground; but they are considerably above the lowest line of drainage which would be taken by a glacier at several miles distance from high gathering-grounds.

The scratches on Claughton Moor, a semidetached hill on the north side of the Central Fells group, are very interesting. They harmonize most thoroughly with the curved arrangement of the others in the Lune district, and were evidently formed in the same way and by the same agent. Yet, unless we are prepared to admit that the direction of the main mass of ice was north and towards the higher ground of the Lake-district rather than south and away from it, we must allow that they were formed by ice pushing uphill at the rate of 800 feet or more in two miles. This view is confirmed by the higher Fells S.S.W. of this, lying in the same line of direction, being completely *moutonnées* over a very large surface, and to a height of at any rate 1500 feet.

I had the benefit of Professor Ramsay's opinion on this matter; and he quite agreed with me that the ice producing these effects must have come from the north, and not from the south. It is clear that local glaciers going downhill have not made them; for in this case the ice has not been travelling in the direction of the greatest fall, but considerably across it. Nor can they have been produced by icebergs grounding, as might be suggested; for then there would be some indication of coasting, whereas these markings are all nearly parallel and going up the hill instead of along it. Nor will an ice-foot explain it; for then we should have scratches radiating from the higher ground. In short, I can conceive of no arrangement but that of land-ice pushed up over this hill by pressure from behind, and obliged to maintain a definite course by ice to the right and left of it.

Now let us look at the set of north-and-south scratches on the north flank of the Central Fells.

It might be suggested that they are due to the shedding of ice to the north from those Fells; but, on the other hand, they are close to the valley of the Wenning, a river which runs from the east to join the Lune, and which would under a system of separate glaciers drain the ice of a considerable part of the high ground about Ingleborough, as well as the northern flank of the central moorlands. Such a valley-glacier would require a considerable width for its channel; and the ice in that would proceed exactly at right angles to the path indicated by these striæ; and they show no signs of turning to run into the Wenning glacier. They cannot be clearly explained by the grounding of icebergs; for icebergs we know are governed in their course more by currents than by winds, and it is improbable that a current five miles broad would impinge upon land without giving some signs of its being deflected. Upon the whole I incline to the opinion that these scratches also belong to the same system as the remainder of the Lune scratches, and that they represent the passage of ice over the Central Fells by a movement from the north—a supposition which is somewhat strengthened by the great smoothing to which these Fells up to their summits have been subjected, all the ordinary stratigraphical features having been obliterated.

Ingleborough District.—Another very interesting set of scratches has been found by Mr. Hughes and myself on the east flank of Ingleborough; they are running in a curved line, pointing to one another, and rising as they proceed from north to south. They curve from S. 10° W. to W. 40° S., and in so curving rise from 1225 feet to 1350 feet. The curve taken by them seems to be caused by the ice rounding Simon's Fell, the east shoulder of Ingleborough. They are on the edge of a long moraine-like mound, which takes the same direction as the scratches. I confess I have some difficulty in seeing at what portion of the glacial period these were made. That they were made by a glacier is very probable; but if so, the glacier which formed them must have been at least four miles in breadth. They certainly do not show any signs of having been formed by any small local glaciers which had their birth on Ingleborough; for they are transverse to the course of any such glaciers. It is possible that the moraine-like mound may have been what was left of the till of the ice-sheet between the scour produced by the dwindling glacier of the Ribble valley and a small glacier descending from the hollow on the south side of the summit. In that case they may still be memorials of the great ice-sheet.

On the large limestone plateau south-east of Ingleborough, rudely coextensive with the portion between the 1000- and 1500-feet levels on the map, are many signs of ice-action. They exist chiefly under isolated large boulders supported on little pedestals of limestone rock, in many respects similar to glacier tables; for the boulder has preserved from weather the scratched surface on which it rested, whilst all around the limestone has wasted away to the depth of eighteen inches or two feet. Most remarkable examples of this, to which Mr. Hughes first called my attention*, occur on Norber; and the Silurian boulders there, some of which must have been brought from lower levels in the country north of them, appear to have a rude arrangement along lines which coincide with the direction of the scratches and the line in which they must have travelled from the parent rock.

North, south, and west of Settle many scratches are to be found. They have nearly all a general north-and-south direction. Some of them may have been produced by later glaciers, lying as they do along the bottom of the valley; but others are at elevations up to 1300 feet, and, taken with the scratches on Ingleborough, on the other side of the Ribble valley, would imply a glacier eight miles broad and 750 feet deep. A point worthy of notice is that these scratches are taking a course parallel to the general direction of the watershed, which is not two miles to the east of them.

Bowland Knotts.—From the Central Fells south of Ingleborough a long ridge dividing the Lune and Ribble drainage strikes east towards the Ribble valley near Settle. It is composed of the lowest bed of the Millstone Grits, dipping gently north. Along its edge are many bold and picturesque bastions of rock, forming a fine foreground to the beautiful panorama of the Pennine chain which is seen from here. Close to the highest point, which is crossed by a mountain-road running from Clapham to Slaidburn, on a prominent bluff of conglomerate, I found the most remarkable evidences of ice-action in the whole district. Scratches were seen under drift at an elevation of 1400 feet; the direction was S. 15° E. across the ridge. On another rocky eminence, one third of a mile south-east of the first are more scratches, on the southern side of the ridge; their direction is S. 5° E., and the elevation is about 1325 feet.

If these were produced by a local glacier, what were its gathering-grounds? Not the Fells immediately west; for then the scratches would be at right angles to their present course. Looking along them to the north, the nearest ground even *equalling* this in height is a portion of Ingleborough seven and a half miles distant; and between this and that lies a broad valley excavated to the depth of about 1000 feet. Ingleborough, with its 900 feet only of additional height, could hardly fill up that valley and make itself felt at that distance. If we look south again along the scratches, there is no ground of equal height to help us nearer than Pendle Hill, at *twelve* miles distance, and across *two* broad valleys. The height at which these scratches occur across this ridge is greater than the height of some of the passes across the Fells to the west of it. There can be very little doubt that the ice-stream passed entirely over these Fells.

In the broad valley between Ingleborough and Bowland Knotts, to which I have just alluded, are two distinct sets of scratches at right angles to one another. One runs south-east, the other south-west. The south-east set were probably made when the ice-sheet was not at its maximum, *i. e.* when there was not sufficient lateral pressure or "shouldering" to thrust the ice over Bowland Knotts, and when

* "Notes on the Geology of parts of Yorkshire and Westmoreland," Proc. Geol. and Polyt. Soc. of the West Riding, 1867.

it had to go round, these south-east scratches being generally on lower levels than those to the south-west. They would therefore probably be made at the earlier or later part of the ice-sheet period—most likely the latter; for the ice at its maximum would obliterate the effects of its earlier development. The south-west scratches seem to lead on from those on the high ground north of the valley, and may belong to the same set as those on Bowland Knotts, the change in direction being accounted for by the form of the ground. On the other hand, it is possible that they may be the result of a local glacier later on, finding its way to the valley.

These scratches running in directions transverse to one another call to mind a suggestion which Professor Ramsay made to me some two or three years ago, that it is possible that there may have been undercurrents, so to speak, in the ice-sheet, caused by the form of the ground. That this occurs on a small scale, at any rate in glaciers, I am pretty well convinced. I saw an instance of it on the Zardezan glacier at the head of the Val Pellina in the summer of 1869. A small glacier debouching from a higher level on to the main ice-stream spread so far across it that the median moraine resulting from the junction of the two swept round in a curve nearly to the opposite bank of the main glacier, which was very far from being a narrow one. There could be no doubt that two bodies of ice were moving in different directions, one above the other, for some distance; but I should feel inclined to hesitate before applying the principle on so great a scale to explain the opposing scratches in so broad a valley, especially as they may be explained by better-known phenomena, as I have already shown.

Leading on from Bowland Knotts is another scratch, on the opposite side of the Hodder valley; it trends across the valley and across the ridge on which it lies.

On the Watershed.—About seven miles west of Skipton lies the Great Watershed, here on comparatively very low ground. It runs along a range of hillocks rising to about 700 feet. They are composed chiefly of drift; but in some parts the underlying limestone rises to the surface. Here is the only scratched surface which I have yet found which shows glaciation from west to east. This is not to be wondered at. It lies between the basins of the Ribble and the Aire, at one of the lowest passes in the Pennine range across the watershed of England. Granted such a development of ice as I have already indicated, it is quite impossible that some of the ice should not have been discharged in this direction. I am aware of the difficulties that are raised about the east side of the Pennine chain being so free from drift: but all geologists agree that some, at any rate, does exist; and the patches that are left cannot be considered to have been dropped just as they are, in isolation. The difficulty lies rather in the question, how has the mass of it been removed? That is a question which I cannot undertake in this paper; I do not know the ground sufficiently to hazard an opinion; nor, indeed, does the matter come within the scope of this inquiry.

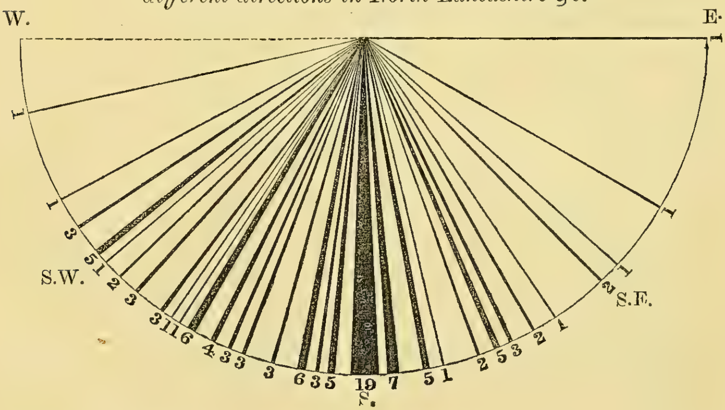
Other scratches seem to run in the direction of East Yorkshire and across the watershed, as about Gisburn, Gledstone, and Barnoldswick.

Clitheroe District.—These last have a general agreement with a scratched "roche moutonnée" on Twiston Moor, on the north-easterly extension of the ridge which culminates in Pendle Hill. It is a complete parallel to those on Bowland Knotts before mentioned; for the scratches are running across the range and not from the summit of Pendle, the highest ground in the neighbourhood. Also the scratches here and those on Bowland Knotts are almost in the same straight line. A proof will be given under the next head that these scratches were formed by ice coming from the north rather than from the south.

In the gorge of the Calder, which cuts across the Pendle range at Whalley, is a very fine large "roche moutonnée" well scratched. It shows pretty clearly by its form that the ice was going up the course of the present river (or southward), not down it (or northward). This rock, as shown by the drift sections on both sides of the ravine, was well covered up by a good thicknesss of Till, and above that again by forty feet of the "middle sands and gravel;" so that it must have been worked by the ice of the land-ice period, not by icebergs, coast-ice, or ice-foot—nor yet by later glaciers; for in that case those later deposits would have been ploughed out. It will be seen, if we put together the scratches in the neighbourhood of Pendle, that to the north of it they appear to be deflected by that eminence, and that to the south they would seem to be coalescing again. I can conceive its being quite possible that the ice-sheet went quite over Pendle; but even then the base of the ice-stream would be influenced in its course by the slopes of the ground, and some such effect as that noticed would be produced.

Close to the south bank of the Ribble, at the junction of Starling Brook, about two miles above Ribchester, are some scratches trending

Fig. 1.—*Diagram showing the proportion of Ice-scratches running in different directions in North Lancashire &c.*



S. 8° W., whereas the valley is running W.S.W. I do not think these can be referred to later glaciers; they would rather seem to belong to the system which crossed over the shoulder of Pendle Hill and went up the Calder valley. One scratched "roche moutonnée" occurs under Mellor Beacon; its direction is W. 13° S., one of the very few instances of scratches with so much of west and so little of south in them, and its direction is probably due to local causes.

The scratches along the coast are not many, the greater part being well covered with drift; but those which do occur seem to agree well in their direction, giving one the idea of a great ice-stream coming to the S.S.E. from the Lake-district, and so damming up the whole of the ice-drainage of the district as to compel it to work across the hills and valleys towards the south, instead of between and along them to the south-west.

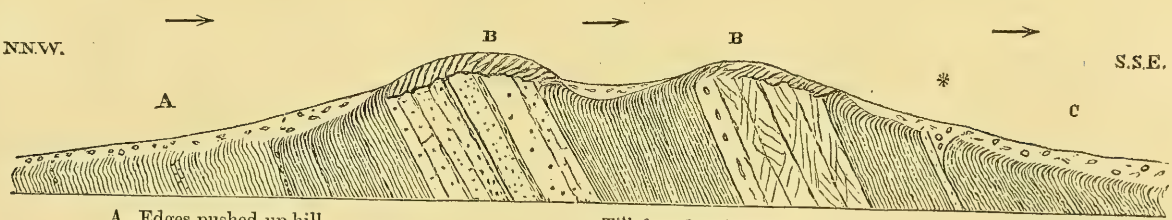
The diagram (fig. 1) gives a summary of the ice-scratches observed, reduced to a common centre. The radii show by their thickness the proportional frequency of ice-scratches in each direction; and the numbers are appended. It is a fact worthy of note that 20 per cent. of the whole are running due south.

II. Other Indications of Ice-movement.

I will now proceed to describe other appearances on the surface of the rocks which seem to point to the passage of ice over them.

The range of the Pendle chain which runs from near Chorley on the western plain to Skipton forms the southern side of the great compound anticlinal to which I have already referred as that in which the Ribble valley south of the Pennine chain is excavated. Its general range is E.N.E.; and therefore its general dip will be S.S.E. But this dip, for the greater part of its length, is at very high angles, from 30° to 60°, and sometimes more. Along the southern flank of these hills you find over wide areas the different laminæ of the beds *at the surface* so turned over in a downhill direction, *i. e.* south, that the angle of dip is either considerably increased, or even reversed, to a depth of one or two feet or more (fig. 2). It is obvious that this is not due to any internal movements of the crust; for it does not penetrate below the surface. I am aware that this phenomenon has been before noticed, and often referred to a subaërial "drag" or "trail" of soft beds to a lower level by reason of gravitation under the softening and loosening influences of rain and frost; but we also get it on the tops of the hills as well as on the slopes, and here gravity would have very little or no field for action. In this position it has been referred to the agency of icebergs grounding on ridges of rock and thrusting the projecting edges of the beds over by the shock. Granting that this is possible, we must yet allow that if an iceberg floating from the north grounded on the top of a ridge, the very fact of its so doing would prevent its exerting this power on the southern flank, which would be in deeper water, and so protected from the abrading power of any floating body of sufficiently light draft to pass over the top of the ridge without hindrance. And any iceberg grounding on the ridge would have to be reduced in bulk by melting, or by breaking itself upon the rock before passing, and would not run

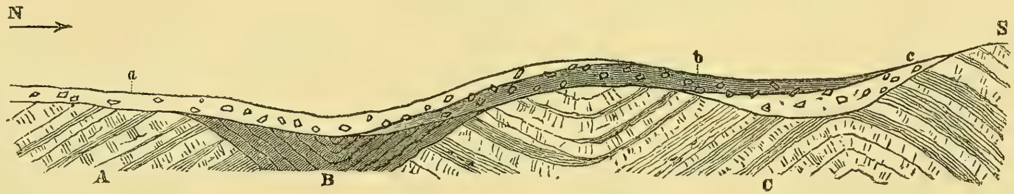
Fig. 2.—*Diagram Section to show the effects of the Ice-sheet on highly inclined rocks along the Pendle Range.*



A. Edges pushed up hill.
B. Edges pushed across the hill.
C. Edges pushed down hill.

* Till forced in between two beds.
The arrows indicate the direction of the movement of the ice.

Fig. 3.—*Sketch Section illustrating the passage of the Ice-sheet as shown in the colouring of the Till by the rocks traversed.*



A. Grey Rocks; *a.* Grey Till from the same.
B. Red Rocks; *b.* Red Till from the same.
C. Grey Rocks; *c.* Grey Till from the same.
The arrow indicates the direction of the ice-flow.

aground again until it came to a reef of less, or at any rate equal depth from the surface of the sea.

But there is yet another position in which this effect is observed; and that is, on the north side of a hill where the dip is into the hill or south (A in the diagram, fig. 2). Here the edges of the beds have been pushed up hill instead of down, though still in the same direction. This cannot in any case be referred to subaërial "drag" or "trail," but exists in spite of it. Again, this might be thought the result of a thrust from an iceberg floating against the ridge; but in so soft a rock as shale, in which this usually though not exclusively occurs, it seems probable that the berg in recoiling would detach the material already loosened by the first forward thrust, and so tend to deface its own work. Can we suppose that in this case the beds have been thrust up hill by an ice-foot fringing the shore, and raised higher at every tide by the accumulation of fresh ice at its base? It seems plausible. Yet, if we admit it, we shall have to allow that whereas on the northern beaches of narrow islets the ice-foot was forcing the edges of the beds upwards and inland, on the southern shores it was dragging them downwards beneath the sea—an hypothesis which cannot be maintained for an instant.

The question then comes to this. Shall we attribute the same effect at A (in the diagram, fig. 2) to an ice-foot, at B to icebergs, and at C to subaërial "drag?" or shall we recognize at both A and B the effects of icebergs, and at C the work of subaërial agents? for no one of these is in itself sufficient to account for all three cases. Such explanations, taking all the facts together, would seem, to say the least of it, to be rather forced and unnatural.

On the other hand, if we can find an agent which will consistently account for this identical effect in all the positions in which it occurs, and also give a solution to several other groups of kindred facts which cannot be readily explained in other ways, we should accept it without hesitation. And such an agent is the great ice-sheet pushing on from its northern gathering-grounds, recruited by the greater elevations on its course, but overriding the lesser, grinding down and smoothing by its weight and friction rocks presenting but a gentle incline, tearing up and turning over the basset edges confronting its approach. For, be it noted, it is only on the southern side of the anticlinal, where the outcrops face the north, that these appearances are to be found; throughout the whole of the northern part of the district, all about the Central Fells, where the beds are dipping north or lying at gentle inclines, nothing of the sort is to be seen. The reason is clear. Where the beds dip north they succeed each other in relation to any force coming from the north, as do the tiles of a roof to the rain; but where dipping south the arrangement is just the reverse. To use a homely illustration, in one case the brushing was with the nap, in the other against it. These superficial movements are common, so far as I have seen, all along the Pendle range. I have seen them some distance south-west of Blackburn. Between the Calder and Pendle Hill, more particularly about Padiham Heights, they are very frequent. Mr. Hull and I, in surveying this ground, found them in nearly every quarry-, brook-, and road-section. The least-favourable position for their preservation is that at A in the diagram. It is only natural that it should be so; for denudation is greater along escarpments than elsewhere, and the effect of subaërial drag would be to destroy them. A very good example occurs in Twiston Brook (just along the line of the scratches on Twiston Moor), where the overturned beds may be seen for a distance of 150 yards along the brook. It is covered and preserved by the overlying Till; and that shows some evidence here, from its materials, of its being merely the waste product of the rocks passed over, and of the direction in which it was being pushed. Another occurs in shale above Moorside, on the north side of Pendle. My friend and colleague, Mr. W. Gunn, has seen similar overturnings of the surface-edges at different points along the chain between Pendle and Skipton. Perhaps the most interesting example of all is one occurring at Blackburn, a representation of which I have embodied in the diagram at the point marked with an asterisk. My friend Mr. James Eccles, F.G.S., called attention to it in a paper read to the Manchester Geological Society; but as it illustrates so well the subject before us I cannot forbear to mention it. It is seen in a road-cutting in a lane near the public park. Beds of shale, sandy flags, and gritstone are dipping southerly at high angles. In one part a bed of soft shale, resting on some harder rock, has been pushed away from it at the surface; and in the angle between the two lies some Till. It seems pretty clear that ice has pushed away the softer bed to a greater extent than the harder; consequently a vacant space was left; and into that a portion of the "moraine profonde" was forced. I know not any phenomena in connexion with the Glacial period which give so vivid a picture of a resistless force working in an undeviating course over hill and dale across the ordinary drainage-channels of the country as this wreck and ruin of all opposing obstacles.

III. The Evidence of the Till.

In speaking of the Till I have no intention of entering upon its well-known characteristics, its local composition, its boulders scratched but not usually rounded, its absence of bedding, &c. I would merely wish to point to those appearances which seem to indicate the direction in which the ice-sheet which formed it travelled; and when speaking of the Till as the product of the ice-sheet, I must remark that much of what is called Till must have been remodelled by the glaciers which were the direct successors, without interruption, of the ice-sheet; and no distinct line can be drawn in this district between the one and the other.

It is a common practice to speak of the Till as being coloured by the rocks beneath; and to a certain extent this is true; but when it is stated that it is always of the same colour as the rock on which it lies, such a remark must either be founded on insufficiency of observation, or is due to the observations having been made in districts where the differences in the rocks passed over are not sufficiently marked to impress their distinctive colouring &c. on the Till.

There is abundant evidence in this district that it is not coloured by the rocks *on which it lies*, but by the rocks *over which it has been pushed*. Where the ice-sheet has been passing for some distance over grey rocks (fig. 3) you may find grey drift upon them; and if, further south, red rock comes on, you will still find grey drift upon it. But if the red rock continue for some distance southwards, you will see the red drift coming in beneath the grey, and the latter tailing out as the former increases in bulk and importance. If, again, continuing your section south, there is a change from red rock to grey, again you will have the red drift resting upon the grey rock for some distance, until the grey drift rises from the rock and intervenes, and so on, the waste product being always on the lee side of the rock producing it. There are several instances of this in the district. Thus, in the valley of the Lune, north of Kirkby Lonsdale, are two long patches of Old Red Sandstone. Further south, in the direction of the ice-movement in Leck Beck, are Coal-measures consisting for the most part of grey rocks, such little red colouring as they do possess being probably derived from the overlying drift. This is almost as red as the Old Red Sandstone, certainly very much redder than the Coal-measures on which it rests, so that the latter cannot be the source whence its colour was derived. There can be little doubt that this drift has passed over the Old Red Sandstone higher up the valley. Again, the patch of Permian south-east of this has acted in a similar way upon the drift which lies immediately to the south of it.

In the Ribble valley, near Clitheroe, is a patch of red rocks supposed to be of Permian age. It lies about 20 miles to the S.S.E. of the last-mentioned; and no other red rocks exist in the country between; grey Till lies upon it. About half a mile south of its southern boundary is a section in Barrow Brook, showing at the base grey Carboniferous shale; on that is grey Boulder-clay, and above it red clay; over this, again, is grey Boulder-clay, the line between the two being very distinct. It is probable that we have here first the Till from the grey rocks south of the Permian, then that from the Permian, and lastly that from the grey rocks on the other side of the Permian. There is no other red rock which could give the colour but this Permian; the next nearest rock of that colour is some Trias in the Ribble, 7 miles or more to the south-west. All these facts point to the southern movement of the ice-sheet.

Again, on the Trias just mentioned, in the Ribble below Stubbin's Wood, on the left bank is a fine section including Pebble-beds, Till, Middle Sands and Gravel, and Upper Boulder-clay. The Trias is faulted down to the south-west against grey Carboniferous rocks. The Till on this Trias is grey; but further to the south you have grey and yellow Carboniferous rocks with red Till reposing on them. The diagram (fig. 3) is a sketch section embodying these observations.

If we allow, for the sake of argument, that there was at one time an ice-sheet over the whole or nearly the whole of this district, and that it slowly disappeared, we must admit that each piece of ground so covered must at one time have been at the edge of that sheet, and that there would be a time when at any particular spot the ice would be losing strength to such an extent that it could no longer thrust forward its "moraine profonde." This would accumulate between the ice and the rock in inverse proportion to the weight and power of the ice. This accumulation of the Till would be an effect constantly following the edge of the ice-sheet in its retreat.

If this were so, we should get very much the kind of section shown in the diagram. The edge of the ice would be working up red drift on to the grey rocks south when it had no longer strength to enable it to abrade the grey rocks themselves, and so in retiring succession. And this is just what I have found in this district in the distribution of colour through the Till.

Of course the Till coloured by the red rocks is not entirely made up of their waste. It contains nearly the same boulders as the grey Till; it is only the matrix which has been coloured by an intimate mixture of red sand or clay.

It is obvious that, although strictly speaking these variously coloured beds have a certain sucession about them, it is a succession so rapid and so brought about by the same causes under the same conditions, that to refer them geologically to different ages would be wholly wrong. Any geologist not acquainted with this changeable character of the Till might think when he found drift of one colour resting with a hard line upon drift of another colour, that he had discovered an unconformability in the Boulder-clays, and classify them accordingly. For this reason I cannot but think that such terms as "the Blue Clay, the Grey Clay, the Yellow Clay, the Clay with Chalk and without," when applied to glacial deposits of particular ages, are cumbersome and misleading. Such characteristics can only hold good as a test of time over a *very* limited area; and even that is doubtful. It is quite possible, nay, it is certain, that in some areas you may have Till of totally different appearance, colour, and material deposited side by side, by the same agents, and under the same conditions, at the same time.

As regards the transport of material, it is an interesting fact that over the greater part of this district there are none but local rocks in the Boulder-clay. In the term local I include any rocks which are derived from any part of the drainage-system in which they are found as boulders. Thus you may find Silurian rocks in any part of the Ribble valley, though they become more scarce in proportion to the distance from the parent rock, which lies chiefly in the neighbourhood of Ingleborough and along a line thence to Malham Tarn.

The ground from which the ice travelled in this district was almost entirely east of the Lake country; consequently you get in the Till none of those granites, porphyries, traps, and ashes which might, did they occur, be so easily traced to their origin. The country from which it passed hither is chiefly a Carboniferous tract; therefore many of the boulders may have travelled a long way overland into the Lune and Ribble valleys and yet appear to be derived from local rocks.

But there is a part of the district which is an exception to this rule. A line might be drawn parallel to the glacial curves along the valley of the Lune and down along the eastern border of the western seaside plain which would roughly represent the boundary of the Lake-country drift.

This direction is rudely represented by the glacial scratches on the rocks beneath. In the northern quarter of the map this boundary may be carried along the Gatebeck Brook, as my friend Mr. Hughes tells me. West of this you find Shap Granite and other Lake-district rocks, but none to the east. The boundary runs thence towards Lancaster. I have found such boulders in Till down the coast by Hest-bank and Bolton-le-Sands. South of Lancaster it probably takes the direction shown by the scratches until past the Central Fells. Here it seems to turn a little more to the east; for foreign boulders may be seen in the neighbourhood of Longridge Fell, although it is possible that they may have been brought thither out of the line by icebergs or coast-ice during the period of the Upper Boulder-clay. At any rate the boundary will go over the western end of the Rossendale anticlinal, and thence to Manchester.

I wish particularly to call attention to the fact that this direction coincides with that of the scratches, and that *it is across the mouths of all the valleys.*

In the part of the district east of Pendle Mr. W. Gunn's observations confirm my own, to the effect that there are no boulders of other than local rocks. He gives only one apparent exception—namely, the existence on the north side of Boulsworth Hill of blocks of quartz rock, a rock which he had seen nowhere in place in the neighbourhood. A rock of this kind, however, I happen to know does occur in Stockdale, near Settle, 18 miles to the N.N.W. of Boulsworth; so that this is no real exception to the rule. Moreover the line of transport coincides with the direction of the ice-sheet's movement as shown by the scratches at high elevation on Bowland Knotts and on Twiston Moor. The scratches at Kingscar in the neighbourhood of the parent rock are not in this direction, but S. 15° W.; as, however, they run along the side of some high scars, this variation is probably local.

It is a point insisted on by some geologists, that wherever either rounded stones or marine shells are found in the Boulder-clay it must be of marine origin. I do not think that either of these supposed characters is infallible. Mr. Croll has shown that the Caithness Till, which contains shells, need not necessarily be marine, but may have been formed by the ice-sheet working over a previous sea-bed and pushing the shells on to the land. In this way shells scratched and broken may be found at very much higher levels than the sea in which they lived and died. They are there as much boulders as the scratched stones along side of them, and are no more evidence of the drift in which they lie having been formed under the sea than Spirifers and Producti found in Limestone River-gravel would be proof of its being marine. In very many places the ice-sheet must have passed over what had previously been the sea-bed; and if its course took it thence inland we should be surprised not to find sea-shells mixed with the drift formed by it. Nor can rolled stones be considered a better test; for under similar circumstances they would be brought up from the old sea-bed on to the land. But rolled stones may be found in abundance in the terminal moraine of any glacier, so that we have their presence most naturally explained. No one who has seen one of those swallow-holes called "moulins" in the ice of a large glacier, and the impetuous swirling torrent which enters it at mid-day hurrying down stones from the surface of the ice, can doubt that *there*, at any rate, is a mill in which rolled pebbles are being manufactured; and such "moulins" must have existed in abundance on the ice-sheet in the times of its decay.

IV. Conclusions.

I have endeavoured to show that in the district with which I am more intimately acquainted, there are proofs of a widespread and almost universal glaciation—that whereas the drainage of this district is to the S.W., the general movement of the ice over it was to the S. or S.S.E. across deep valleys, and over hills of considerable elevation—that this is proved by the scratches on the rocks, the direction and method of transport of the Till, its materials, and their arrangement along lines coinciding with the scratches, as well as by the superficial disturbances of the rocks. I showed that these facts would admit of readier explanation by means of an ice-sheet than by any other glacial agent. But the direction of the movement requires a further explanation. Under ordinary circumstances an ice-sheet would be working down from the watershed to the sea in the direction of the main valleys; but this was not so. There must have been a great barrier along what is now the seaside plain to dam up the mouths of these valleys to a great height and prevent their discharge of ice to the south-west. Just where this barrier should have existed we find evidence of a great stream of ice coming from the Lake-district and bearing with it rock-specimens of that country. This must have been of considerable height and very persistent in its flow to divert the ice-drainage of the basins of the Lune and the Ribble from their natural course; but that it did so is very evident. This barrier was but the line of junction of the ice of the Pennine chain with that from the Lake-district, and to the eye they must have presented only the appearance of one great sea of ice; and this barrier must have been supported or shouldered up by other ice coming from portions of the Lake-district still further west.

After coming to the above conclusions I could not fail to be interested in finding how thoroughly the facts observed by the Rev. J. G. Cumming in the Isle of Man agreed with those which I had met with in North Lancashire and Yorkshire. Mr. Cumming, in his work 'The Isle of Man,' states that the glacial scratches have an almost uniform direction across the island of magnetic east to west, that is from the E.N.E. In speaking of the very local character of the lower portion at least of the Boulder-clay formation, he says (p. 113), "as we proceed westward we shall observe how it changes in composition and tallies in chemical character, as well as in lithological appearance and colour, with that of the subjacent prevailing rock a very little to the eastward of any spot on which we may fix for its examination." Further on, p. 120, he says, "we fall in with pebbles of foreign rocks in the Boulder-clay which must have come from a great distance, from the shores of Cumberland and the south of Scotland;" and this leads him "to the conviction of one great current setting down from the Solway Frith upon these shores and overpowering the effects of local currents caused by the flux and reflux of the tide." He also speaks of the direction in which blocks have been transported agreeing with the scratches on the rocks beneath. At p. 249, he says, "There are phenomena which point to the probability at least that enormous waves with vast carrying force must have swept over the surface of the island. The general appearance of its eastern, as compared with its western side, described by Swedish naturalists under the term *Stossseite* or weathered side, indicates in some measure that fact, and also the direction of that action. But the evidence which tends most powerfully to the establishment of such a view is to be read in the phenomena presented to us on the western side of South Barrule. We have noticed there on its western side, and even within a hundred feet of its summit, large boulders of the same granite which is developed on its eastern side more than 600 feet below the summit. No simple carrying-action of icebergs can have transported these blocks up the very steep eastern face of the mountain, and so over to the other side; but we can imagine the extraordinary action of great waves acting on masses of ice charged with these granitic blocks and bearing them to a considerable elevation above the then sea-level. We must either grant this, or suppose an elevation of the mountain-chain to the westward of the granitic boss since the deposit of the blocks on the top and western side of South Barrule; but of such elevation no independent evidence has been yet discovered." So far Mr. Cumming. This was published in 1848; and though the conclusions drawn from the facts are a little out of date, there can be no doubt of the accuracy of his observation of the facts; and none of his facts, so far as my knowledge goes, are antagonistic to the former existence of a great ice-sheet filling up what is now the Irish Sea, between the Lake-district and the Isle of Man, and passing over that island.

If now we pass on to South Lancashire and Cheshire, we may take the evidence of Mr. Morton as to the glaciation of the basin of the Mersey. In a paper read to the British Association at Liverpool in 1870, he modified his former views as to the scratches which he had discovered being due to a glacier, and having found fresh localities where these existed at some height above the bottom of the valley both on the Cheshire and Lancashire side of the Mersey, attributed them to an ice-sheet working down the Mersey valley to the N.W. The exact direction of the scratches is N. 35 W.; and they are covered by Lake-district débris in Boulder-clay. The scratches Mr. Morton supposes to have been made by the ice-sheet before a submergence, during whch they were covered up by Boulder-clay brought from the north by floating ice.

It will be seen that these scratches were nearly parallel to, only a little more easterly than, those along the Lancashire coast further north, and coincide with the general southern glaciation of North Lancashire. One thing is certain, that if the ice-sheet was working to the S.S.E. in North Lancashire it could not be working to the N.W. in South Lancashire. I would suggest that here too there was a general movement of the ice-sheet *from* the Lake-district, and that the low basin of the Mersey was one of the mouths by which the great ice-basin now represented by the Irish Sea was discharging itself.

If we turn now to Anglesey, Professor Ramsay, to whom my acknowledgments are due, showed many years ago, in 'The Old Glaciers of North Wales,' that the glaciation of that island and the low ground of Caernarvonshire is not in a direction radiating from the mountains, as the highest ground, but that the scratches are from the N.N.E., and that here you get foreign blocks from the hills of Cumberland. On the opposite coast of Ireland the glaciation, as shown by Mr. Close in his Map (Geol. Mag. 1867), is rather along the coast than from the land. Professor Phillips also tells me that he has observed the same at Bray Head, co. Wicklow. Just as the glaciation in Lancashire and Cheshire bore to the east of the mountains of North Wales, so in Anglesey it bore rather to the west, and St. George's Channel was another great outlet on the south for the ice-sheet.

APPENDIX.

TABLE OF ICE-SCRATCHES IN NORTH LANCASHIRE AND ADJACENT PARTS OF YORKSHIRE AND WESTMORELAND.

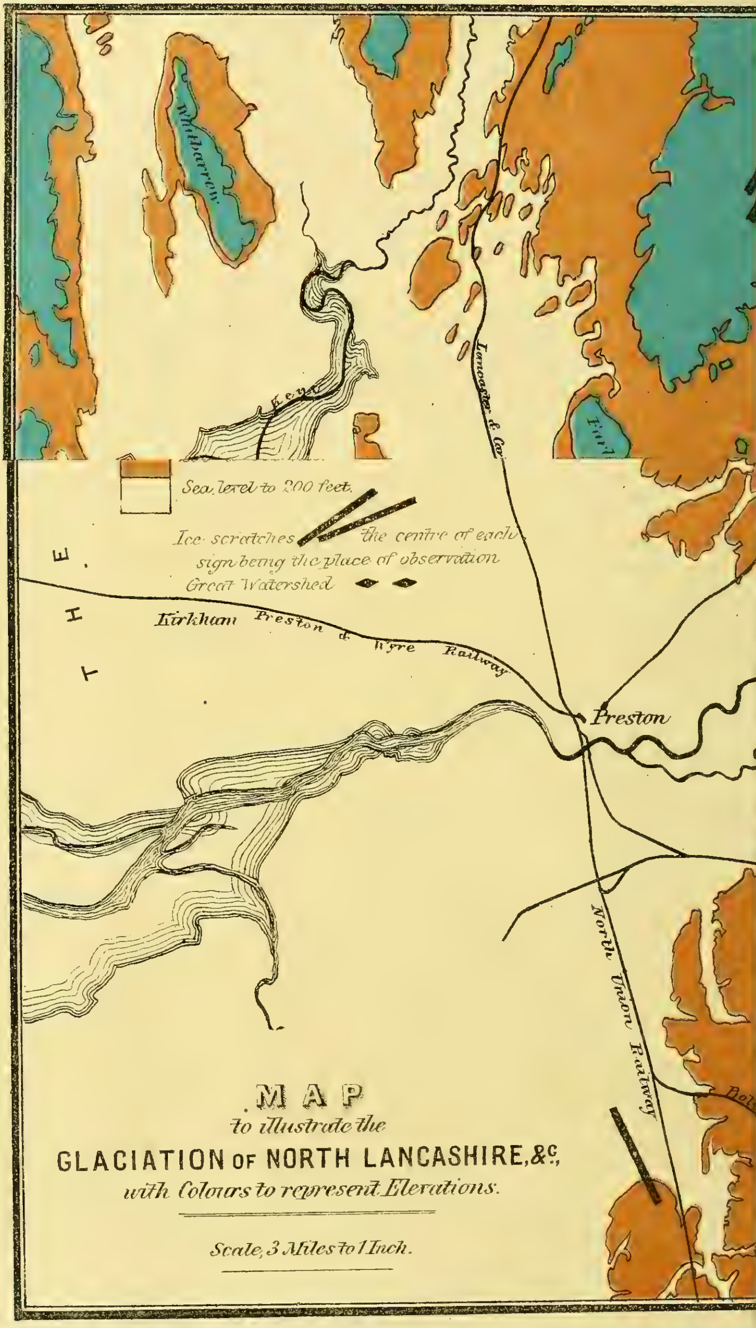
County.	6-inch Map.	Locality.	Height above the sea in feet*.	Direction.
Lancashire.	19	Above Thwaite Wood, Capernwray Hall...	325	W. 40° S.
	,,	Above Whittington Park	550	S. 32° W.
	,,	New Park, Whittington	525	W. 40° S.
	,,	Long-Field Tarn Pasture	475	S. 30° W.
	25	Redwell Quarry	300	S. 32° W.
	,,	Quarry near Storrs Hall	230	W. 30° S.
	26	Park Lane, near Winnington	313	S. 5° E.
	,,	How Clough, near Winnington	280	S.
	,,	Quarry half a mile W. of Park House, Hindburn	535	S. 15° W.
	29	St. Patrick's Chapel, Heysham	35	S.
	,,	Chapel Hill, Heysham	35	S. 10° W.
	,,	Opposite Heysham Lodge	40	S. 40° W.
	,,	Money-Close Lane, Heysham	35	S.
	30	N. of Heysham Moss	25	S. 5° W.
	,,	W. of Heysham Moss	30	S. 5° E.
	,,	S. of Brown Moss	30	S. 5° E.
	,,	Lancaster Moor	330	S. 5° E.
	31	Claughton Moor	630	S. 25° W.
	,,	Hornby Moor	875	W. 35° S.
	,,	Whitmoor	900	S. 30° W.
	,,	Another on Whitmoor	925	S. 30° W.
	,,	East of Intack House, near Caton	580	S. 10° W.
	,,	S.W. of Intack House, near Caton	510	S. 10° W.
	34	Ellel Crag	325	S.S.E.
	,,	Bazil Point	15	S. 5° W.
	46	Wilkinson's Quarry, near Chipping	325	W. 42° S.
	,,	Wilkinson's Quarry, near Chipping	325	S. 30° W.
	47	Chatburn Station, Bold-Venture Quarries	330	S. 30° W.
	,,	Pimlico Quarries	300	S. 20° W.
	48	Twiston Moor	1050	S.S.E.
	54	Bank opposite junction of Starling Brook and Ribble	90	S. 8° W.

* Estimated from the contours on the 6-inch Ordnance Map.

County.	6-inch Map.	Locality.	Height above the sea in feet*.	Direction.
Lancashire.	55	Under Whalley Nab by the Calder.........	200	S. 10° E. S. 25° E.
	56	Dole House, Roughlee	775	S. 5° W.
	62	North side of Mellor Beacon, Blackburn...	475	W. 13° S.
	77	Euxton Mills, N. bank of Yarrow	100	S.S.E.
	„	Grey Heights, East of Chorley	......	S.S.E.
Yorkshire.	96	Long Kin, the Allotment, Ingleborough...	1350	W. 40° S.
	„ †	Alum Pot Beck, Ingleborough...............	1225	S. 10° W.
	„	Under large boulder, Fell Close, Ingleborough	1275	S. 10° W.
	„	Beck below Shooting House, E. side of Ingleborough	1350	S.S.W.
	„	Water Swallow, the Allotment, Ingleborough	1375	S. 35° W.
	97	Fair-Bottoms Barn	1100	S. 35° W.
	112	N. of High Bottom	340	S.
	„	Another	330	S.
	„	North of Tennant House, High Bentham	510	S.
	113	W. side of Clapham Farm.....................	600	S.E.
	„	Norber...	950	S. 20° W.
	„ †	Wharfe Mill-dam	550	S. 30° E.
	„ †	W.S.W. of Crummack	1150	S.
	„ †	Three quarters of a mile S. of Crummack	800	S.
	„ †	200 yards E. of last	800	S. 10° E.
	„	Newby Cote, above the Quarries............	775	S. 35° E.
	114	Foredale	900?	S. 7° W.
	„	Helwith-Bridge Slate-quarry	725	S. 5° W.
	„	John Batty's Wood, Railway-bridge	700	S. 10° W.
	„ †	Tongue Gill, 1 mile N.E. of Stainforth ...	975	S.S.W.
	„ †	New Close, Silverdale, Stainforth	1220	S. 15° W.
	„ †	Catrigg Beck, Stainforth	1075	S. 25° W.
	131	Copy House, Cow Gill	540	W. 40° S.
	„	Kettlesbeck, near Railway-bridge	475	S.E.
	„	E. of Low-Kettlesbeck House	525	W. 35° S.
	„	One-third of a mile N. of High Kettlesbeck.	675	S. 40° W.
	„	Another	675	S.W.
	„	S.E. of Bridge to High Kettlesbeck.........	670	S. 40° W.
	„	North of Lingthwaite, Kettlesbeck	600	S. 20° W.
	„	One-third of a mile S.S.W. of Blaithwaite	680	S.
	„	Craven Lane	625	S. 10° E.
	„	Lawkland-Hall Wood	540	S.
	„	E. of Sandford Brow	700	S.
	„	E. of Wham Lane	775	S. 10° E.
	„	Another	740	S.S.E.
	„	N. of Cocket Moss	775	S. 10° E.
	„	In brook N.W. of Lower Sheep Wash......	625	E. 30° S.
	„	On crag, N.W. of Black Hill	1050	S. 25° E.
	„	Bowland Knotts, E. of gate	1400	S. 15° E.
	„	One-third of a mile E.S.E. of gate	1325	S. 5° E.
	132	N. of Cocket Moss	760	S.
	„	E. of Cocket Moss	750	S.
	„	W. of Hollin-Hall Wood	550	S.
	„	By Laithes, S.S.E. of Green..................	535	S.

* Estimated from the contours on the 6-inch Ordnance Map.

† For these observations I am indebted to my friend and colleague, Mr. T. McK. Hughes.



Whitbarrow
Kent
Lancaster & Car
Sea level to 200 feet.
Ice scratches the centre of each sign being the place of observation
Great Watershed
THE
Kirkham
Preston & Wyre Railway
Preston
North Union Railway
MAP
to illustrate the
GLACIATION OF NORTH LANCASHIRE, &c.
with Colours to represent Elevations.
Scale, 3 Miles to 1 Inch.

County.	6-inch Map.	Locality.	Height above the sea in feet*.	Direction.
Yorkshire.	132	S. of Giggleswick Tarn	550	S.
	,,	Under Kingscar, Victoria Cave, Settle	1300	S. 15° W.
	148	Chapel-House Lane, Merrybent	722	S. 30° W.
	,,	Quarry House, Stephen Moor	810	S. 30° E.
	,,	Stephen-Moor House	850	S.
	,,	Tosside Fold	675	S. 20° E.
	165	Limestone Quarry, near Dunnow House	475	S.
	,,	Gravel Pit near Dunnow, further S.W.	450	S.W.
	,,	Baygate	585	W. 35° S.
	,,	Harris's Lathe, Roddel Chapel	640	S. 20° W.
	,,	Sandstone Quarry, near Guy's, Champion	910	S.
	,,	West of Champion House	860	S.S.W.
	,,	Sandstone Quarry E. of Champion	880	S. 5° E.
	,,	Owlet Moss	880	S. 7° W.
	,,	Gill Beck	485	S. 5° E.
	166	Gisburn Toll-bar, Skipton Road	459	S. 25° E.
	,,	Quarry, S.W. of Gladstone	525	E. 42° S.
	,,	Swinden-Moor Head	655	E.
Westmoreland†.	40	Holme Fell, above Jordan Wood	800	S. 35° W.
	43	Killington Common	650	S. 33° W.
	,,	Killington Common	600	S. 25° W.
	,,	Killington Common	800	S. 25° W.
	44	Thirn Gill	885	S. 5° W.
		Thirn Gill	885	S. 20° E.

* Estimated from the contours on the 6-inch Ordnance Map.

† For these observations I am indebted to my friend and colleague, Mr. T. McK. Hughes.

DESCRIPTION OF PLATE XXX.

Map to illustrate the glaciation of North Lancashire, with colours to represent elevations. Levels reduced from the one- and six-inch Ordnance Maps. Scale, 3 miles to 1 inch.

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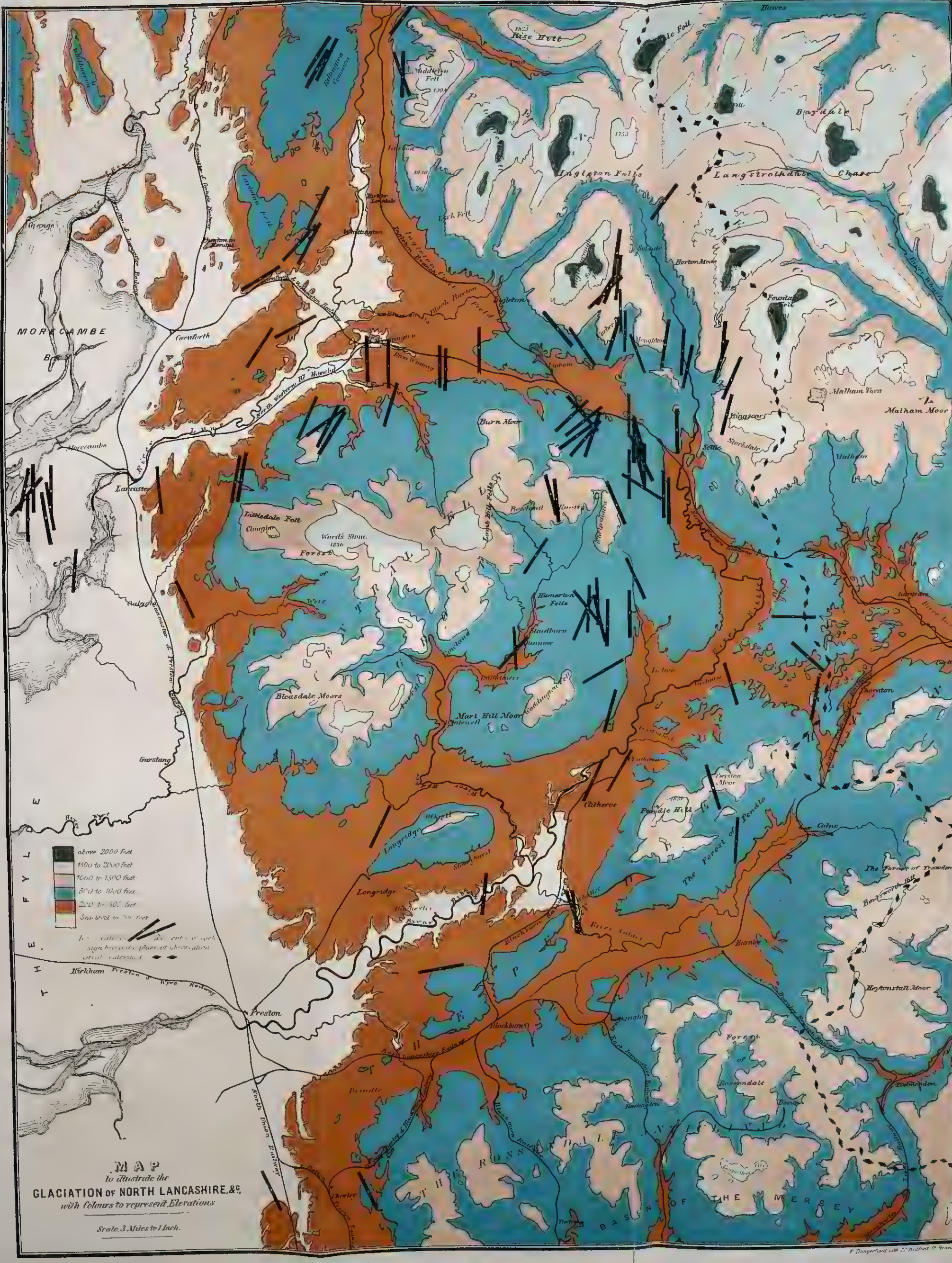
5. *On the* Mammalia *of the* Drift *of* Paris *and its* Outskirts. By Professor Albert Gaudry, F.C.G.S.

(In a letter to W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S.)

[Abstract.]

In this paper the author briefly indicated those mammals the remains of which have been discovered in the Pleistocene or Quaternary deposits of Paris and its vicinity. His list includes flint implements as evidences of the existence of man, and bones of the following species:—*Canis lupus*, *Hyæna crocuta* (*spelæa*), *Felis leo* (*spelæa*), *Castor trogontherium* and *fiber*, *Elephas primigenius* and *antiquus*, *Hippopotamus amphibius*, *Rhinoceros tichorhinus* (a Rhinoceros of doubtful species), *Sus scrofa*, *Equus asinus* and *caballus*, *Bos primigenius*, *taurus* ?, and *indicus* ?, *Bison priscus* and *europæus*, and *Cervus tarandus*, *Belgrandi*, *megaceros*, *canadensis* ?, *elaphus*, and a small species.


MAP
to illustrate the
GLACIATION OF NORTH LANCASHIRE, &c.
with Colours to represent Elevations
Scale, 3 Miles to 1 Inch.
above 2000 feet
1500 to 2000 feet
1000 to 1500 feet
500 to 1000 feet
200 to 500 feet
MORECAMBE
Carnforth
Lancaster
Garstang
Preston
Longridge
Blackburn
Clitheroe
Colne
Burnley
Settle
Ingleton
Ingleton Fells
Langstrothdale
Chase
Hawes
Malham Moor
Malham Tarn
Malham
Burn Moor
Ward's Stone
Forest of
Bowland
Bleasdale Moors
Littledale Fell
Hamerton Fells
Waddington Fell
Pendle Hill
The Forest of Pendle
Forest of Rossendale
THE ROSSENDALE
BASIN OF THE MERSEY
THE FYLDE
Kirkham
Preston & Wyre Railway
Heptonstall Moor
Todmorden

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPER.

FURTHER NOTES *on the* GEOLOGY *of the* NEIGHBOURHOOD *of* MALAGA.

By M. D. M. D'ORUETA.

(Communicated by the late Sir R. I. Murchison, Bart., F.R.S., F.G.S.)

[Read February 7, 1872.]

(Abridged.)

SINCE my former paper on this subject (see Q. J. G. S. vol. xxvii. p. 109), I have visited several parts of the mountain-chain near Antequera, and made another expedition to the Torcal, in order to observe more carefully the order of superposition of the rocks of the Sierra and those of the plain of Antequera, and I have collected some facts justifying my proposed classification. The rocks of the Torcal, as well as the other parts of the chain, are composed of a very fine and compact limestone, white in some places, but becoming red throughout the centre of the ridge, owing to infiltrations of oxide of iron. They form very beautiful marbles, called "Jaspon blanco" or "Jaspon rosso" (according to their colour), and extensively employed for ornamental purposes in several parts of this province. At the foot of the Torcal they pass into a coarser calcareous stone, called in Antequera "Piedra Javaluna." These rocks extend for some distance towards the plain, but soon become a sort of conglomerate, composed of round calcareous pebbles, united by a cement of the same material. About a mile and a half from the foot of the Sierra, they are seen to cover, in conformable stratification, beds of an almost pure sandstone, of a soft and easily disintegrable character, containing many fossils, the most abundant being *Gryphæa virgula*, which is characteristic of the Kimmeridge Clay both in England and on the continent of Europe. The soil seems, in some parts, to be sown with *Gryphææ*; so that loads of them might be collected in a very short time. This was the cause of an error into which I fell in my former communication. The road was very rough and hilly; and we were riding by the side of a rivulet, when the fossils were brought to us from a neighbouring field, where we could see the Javaluna conglomerate cropping out; and as we could not at that moment perceive any other formation, we imagined that they belonged to those rocks. On this second occasion I satisfied myself that they are imbedded in the sandstone, and that those we found on the road had been carried thither by the action of water. Another common fossil of the Kimmeridge Clay is also found in this formation, namely *Ostrea deltoidea,* but not so abundantly as the *Gryphœa.*

I think that the verification of these two well-known fossils will leave little doubt that the siliceous formation on which the Torcal sandstone reposes corresponds with that which in England constitutes the second division of the Upper Oolite; and consequently the rocks which cover it, if they belong to the Jurassic group, must either fall into the same division, or perhaps belong to the Portland series.

In case there should still be any doubt about the Jurassic character of these fossils, and any one should be inclined to believe that they have more resemblance to Cretaceous forms, I will mention another fact which has lately come to my knowledge. By inquiring among the inhabitants of the villages, I have ascertained the existence in the "Tajos del Gaitan" of a calcareous deposit, whiter and of softer texture than the above-mentioned marbles, over which it has been described to me as lying unconformably. It contains fossils, and one form in particular, which must be *Terebratula diphya.* M. de Verneuil seems also to be aware of the existence of this deposit; for in his map he marks the "Etage Tithonique" as existing in this locality. My friend Mr. J. Macpherson, of Cadiz, writes to me that he has found the above-mentioned *Terebratula* in some deposits in close connexion with limestones of acknowledged Jurassic origin. I am not aware that this fossil has ever been found in any stage but that called Tithonic, the position of which has been the subject of much discussion; but even if it corresponds with any member of the Cretaceous group, it can only be with the oldest known division of the Neocomian.

Having concluded the subject of classification, I will now present some reflections on the peculiar condition of the Torcal. It has been generally assumed that the condition of the Torcal is due to subaerial denudation after it had attained its high level; but considering the great extent of the phenomena and the different ways in which rocks can be influenced by rain, frost, heat, dryness, or other physical causes, in my late expedition I again carefully examined the district, in order to see if I could observe any signs of subaerial denudation, and reconcile myself to the idea that the Torcal had been influenced by the same physical causes as the surrounding regions, and merely acted upon more powerfully on account of its central position, the horizontality of its strata, or some other peculiarity in its condition. My observations, however, have confirmed my previous opinion that the agent which modelled the fantastic rocks of the Torcal was of a quite different nature from that which shaped the rest of the chain.

In other parts great fissures have been produced, which, being enlarged by the rain-water descending from the slopes, have become wide valleys and precipitous ravines. Such is the condition of the "Tajos del Gaitan" and of several parts of the "Sierra de Abdalagis." In these cases, however, the rocks are regularly worn, without any grooving or different kind of shape, plainly indicating that they have been subject for ages to the same physical action. Thus, a river has shaped its course through the midst of this region, and its powerful denuding effects can be traced at the present day; but, although we may examine its successive channels from top to bottom, we can find nothing that resembles the rapid force exerted upon the Torcal. The "Sierra de la Chimenea" and that of "Las Cabras," which surround this mountain, are conical and quite different in shape: in them we can see the regular effects of the weathering influences on their peculiar calcareous stone; and I see no reason why everywhere else it should not have been acted upon in the same manner, especially as the stratification in some of these places is as horizontal as in the Torcal. Otherwise we might explain the greater effect then produced, by ascribing it to the coincidence of the course of the water with that of the beds. Moreover the whole chain is equally exposed to any alternations of weather that may have taken place. A very rapid and powerful agency must have been required to produce the extraordinary condition of the Torcal.

The tabulated shape of the top of the Torcal renders it probable that the original summit has been washed away; so that there a greater force has been exerted than on the slopes. Almost all the basins have profound fissures in their centre; and the mountain is pierced from top to bottom by crevices and vertical caverns. Prof. Ansted has observed that the volcanic rocks which have lifted the Sierra Nevada and other chains of Andalusia are rarely if ever to be seen at the surface. Now it is remarkable that the foot of the Torcal is one of the few places where these rocks can be found; for on both sides a peculiar sort of greenstone is seen in some abundance. I am therefore inclined to believe that this mountain has been the centre of the upheaval occasioned by the above-mentioned rocks, not only because it seems to be the point of connexion between the adjoining Sierras, but also on account of its being situated in the centre of the region and its strata being so horizontal, whilst those of the extremities, as, for example, at the Tajos del Gaitan, have been thrown into all sorts of inclinations, even becoming vertical at the place called "El Cherro," at the extreme end of the chain.

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

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1. *On the* Rocks *of* Native Iron *discovered in* 1870 *in* Greenland. By M. Daubrée.

[Comptes Rendus de l'Académie des Sciences, Tomes lxxiv. & lxxv.]

M. Daubrée has received from M. Nordenskiöld some specimens of native iron discovered by the latter at Ovifak, in Greenland (see pp. 1 and 44 of the present volume of the Quarterly Journal). In these papers he gives the results of his examination of them. They were regarded as of extraterrestrial origin by their discoverer and other Swedish chemists; and this view has been supported by M. Wöhler (Nachr. Kön. Gesellsch. Göttingen, 11th May, 1872), whilst the opinion has been expressed by some geologists in this country (Quart. Journ. Geol. Soc. *loc. cit.*) and in France (Bull. Soc. Géol. Fr. xxix. p. 175) that they might be of eruptive origin.

The four specimens examined by M. Daubrée were taken from the basaltic rock. The fragment first specially referred to is a blackish metallic mass, which, when polished, shows imbedded in the mass a network of white lamellæ (like schreibersite) and irregularly scattered brassy grains (troilite). The author describes the method of analysis employed in the examination of this mass, and gives the following as its results, which differ in some respects from those given at p. 45 :—

Iron, metallic		40·94	Total 71·09
Iron, combined with oxygen, sulphur, and phosphorus		30·15	
Carbon, combined		3·00	Total 4·64
Carbon, free		1·64	
Nickel		2·65	
Cobalt		0·91	
Sulphur, in the state of sulphide		2·70	
Arsenic		0·41	
Phosphorus		0·21	
Silicium		0·075	
Nitrogen		0·004	
Oxygen		12·10	
Water of constitution		1·95	
Water, hygometric		0·91	
Soluble substances: Sulphate of lime	1·288	1·354	
Soluble substances: Chloride of calcium	0·039		
Soluble substances: Chloride of iron	0·027		
Chromium, copper and loss		1·01	
		100·00	

In a second paper M. Daubrée distinguishes three types among the so-called meteorites of which he has received specimens, namely:

—1, the black metallic mass of which the analysis is given above; 2, a light-grey metallic mass resembling ordinary iron; and, 3, a dark-green lithoid mass of silicates in which the metallic substance is disseminated in globules and grains. The second type consists of a pulverizable portion and numerous malleable lamellæ, containing respectively 74·2 and 82·4 per cent. of iron; but as the former is in much less quantity than the latter, the total amount of iron must approximate to the latter number. The metallic globules of the third type, when polished and treated with acid, show figures indicating the presence of silicates very finely disseminated through the mass; in one of them the silica representing these silicates reached 11·9 per cent. of the total weight. Both these types were investigated in the same way as the first for the determination of the free and combined iron and carbon, the silicium, and water. The following are the results given:—

	First type.		Second type.		Third type.	
Iron, metallic	40·94	71·09	80·8	82·4	61·99	70·1
Iron, combined	30·15		1·6		8·11	
Carbon, combined	3·00	4·64	2.6	2·9	3·6	4·7
Carbon, free	1·64		0·3		1·1	
Silicium	0·075		0·291		not determined.	
Water	2·86		0·7		,,	

The author gives a similar comparative table of the proportions of soluble salts contained in the three types, as follows:—

	First type.	Second type.	Third type.
Sulphate of lime	1·288	0·053	0·047
Chloride of calcium	0·039	0·233	0·146
Chloride of iron	0·027	0·089	0·114
	1·354	0·375	0·307

Copper was detected by spectroscopic analysis in the solutions of 2 and 3 in hydrochloric acid.

With regard to the nature of these masses, M. Daubrée says that the presence of nickeliferous iron and of schreibersite seems to justify the name of meteorites that has been applied to them. In the third type the distinctness of the crystals of the silicates contrasts with the confused and imperfect state of crystallization usual in meteorites. Free oxide of iron is rare in meteorites; in the masses from Ovifak much of the iron is combined with oxygen; and the presence of an abundance of carbon in them, free or combined with iron, is another equally remarkable fact. By the last two characters the masses from Ovifak approach the carbonaceous meteorites, from which, however, they differ in other characters, and especially in their aspect, and must be regarded as forming a new type in the series of meteoritic rocks. But while differing more or less from known meteorites, they are still more clearly distinguished from terrestrial rocks, even dolerites and basalts, as in these native iron combined with nickel and cobalt, or phosphides and sulphides of iron have never been detected.

Suggesting but not adopting the notion that below the ordinary eruptive masses there may be others becoming more and more rich in iron, which, under certain circumstances, may reach the surface (although, as he says, Greenland would seem to be a peculiarly favourable region for the occurrence of such a phenomenon), the author indicates that the basaltic rocks themselves, which contain more than 20 per cent. of oxide of iron, may, on reaching the surface, have undergone a partial reduction ; and in support of this view he points out that between 69° and 72° N. lat. Greenland contains numerous thick layers of lignite, especially in Disco Island, where Ovifak is situated.

The author calls attention, however, to the fact that the singular mixture of substances which are decomposed or set free at a very moderate heat, seems to be incompatible with the temperature through which these bodies, from other circumstances, may be assumed to have passed, and indicates that this mode of association is presented also by the carbonaceous meteorites belonging to four falls which have taken place since the beginning of this century*. In other meteorites free oxide of iron has very rarely been indicated; those which are rich in carbon contain their iron almost entirely in the state of oxide. The author refers to a reaction investigated by Stammer and Grüner in which oxide of carbon in presence of an oxide of iron becomes split, producing a deposit of carbon partly combined with iron and partly mixed with the oxide of that metal, which seems to him to present some analogy with the constitution of the carbonaceous meteorites.

The presence in these masses of so large a proportion of soluble salts was at first regarded by the author as distinguishing them from meteorites; but in his second paper he shows that in several cases chlorides and other soluble salts have been detected in meteorites by C. T. Jackson, Lawrence Smith, Shepard, and others, and remarks especially upon the absence of chloride of sodium from the masses found at Ovifak. He notices further that, from the mode in which the polished surfaces become moistened and oxidized during exposure, it is evident that the deliquescent salts are not uniformly distributed throughout the masses, and that the preservation of the masses on the coast of Greenland is due to the feeble tension of the vapour of water in the polar regions, and would by no means be manifested under other climatic conditions. Whilst recognizing the probable meteoritic origin of these masses, the author thinks that they seem to elucidate the nature of the deeper-seated parts of our globe. [W. S. D.]

2. Geology *of the* Aleutian Islands. By E. von Eichwald.

[Proc. Imp. Geol. Inst. Vienna, May 7, 1872.]

These islands, which are remarkable for their glaciers and serial volcanoes, form, with the peninsula of Aliaska, a geological whole, and seem, according to the author, to be in process of elevation, so

* These are the falls of Alais (15th March, 1806), of Cold Bokkeweld, Cape of Good Hope (13th October, 1838), of Kaba, in Hungary (15th April, 1857), and of Orgueil (14th May, 1864).

that a further union of some of them is probable. They are characterized by great diversity of the rocks composing them, which include crystalline slates and numerous eruptive rocks, especially of the trachytic and basaltic groups, occurring side by side with sedimentary deposits of various ages. The Silurian formation is indicated by a fragment of a species of *Lichas*; and some red sandstones, probably the analogues of similar rocks in Siberia, may also be referred to the Silurian, on account of their containing certain Trilobites, Orthoceratites, and Brachiopods. On Aliaska there is a black sandstone, with *Ancella mosquensis*, which the author refers to the Neocomian. Other deposits are said to belong to the Gault and the Turonian. Aliaska also furnishes Miocene fossil plants.

[COUNT M.]

3. *On the* GEOLOGICAL STRUCTURE *of the* ITALIAN PENINSULA. By Prof. ED. SUESS.

[Proc. Imp. Geol. Inst. Vienna, May 7, 1872.]

THE true Apennines, or, in other words, the chain of the Gran Sasso, the main orographical line of Italy, present no rocks identical with those of the central chain of the Alps, and, when compared with the Alps, exhibit only the structure of a folded secondary zone, analogous to the cliff-zone of the Carpathians. The true tectonic axis of the Apennines runs parallel to the western border of Italy, from the Gulf of Genoa, through the Tyrrhenian sea towards Calabria. Old schistose rocks, such as occur in the inner zone of the Alps, are present throughout the Apuan Alps, the islands of the western coast, and the "Catena metallifera," and extend to the promontory of Circe and the island of Jannone, far to the south of Rome, in larger and smallei chains, reefs, and fragments resembling the scattered remains of a ruined mountain-chain. In the south, in Calabria and the north-eastern extremity of Sicily, crystalline rocks appear over a great extent; and here the tectonic significance of the above-mentioned fragmentary old schists is clearly manifested. Gneiss appears near Messina in the Peloritan region, followed towards the south-west by younger deposits; and even near Taomina these old deposits are overlain by Devonian, Triassic, and Liassic beds, &c. This succession of beds, lately described by Prof. Seguenza, has its analogue rather in the Northern than in the Southern Alps, and therefore represents the stratigraphical head (*Schichtenkopf*) of a western subsidiary zone.

The mountains of Calabria are of decidedly Alpine type. Three central *massifs* may be traced among them, viz.:—1. The *massif* of Aspromonte, falling abruptly on all sides towards the Tyrrhenian sea; 2. the *massif* of the Sila; 3. the *massif* of Monte Cocuzzo, which is also abrupt towards the Tyrrhenian sea.

The large white limestone chain in the Basilicata, which rests on the old crystalline rocks to the east of the ancient Sybaris, constitutes the stratigraphical head of the eastern subsidiary zone. At its foot, near San Donato, cinnabar is worked in red quartzite, just as in the Devonian of the Southern Alps. Thus between Taormina and Sybaris there exists a great portion of an Alpine central chain, the Apennines being its north-eastern and Sicily a part of its south-western subsidiary zone; and the older rocks of the "Catena metallifera" are to be regarded as the real tectonic continuation of this southern central chain.

From Palermo to Messina, and from Messina to Cape Spartivento, and to the island of Capri, the Tyrrhenian sea is surrounded by lines of fracture; and even beyond this part, the promontory of Circe to Elba and Spezzia, the mountain-range is immersed and broken up. Beneath the Tyrrhenian sea lies the tectonic axis of the Italian peninsula, which in its present state represents only the ruins of the great old Tyrrhenian mountain-range projecting from the sea and its younger deposits. The extra- and intra-Alpine depressions in the Vienna Basin are represented in Italy by an intra-Tyrrhenian (Tuscan) and extra-Tyrrhenian (Bononian) depression.

The localities of active volcanic eruption in Italy are for the most part situated along the lines of fracture, such as, especially, the great zone running from Tuscany over the Alban mountains to the Phlegræan fields and Vesuvius, whilst more crowded groups of volcanoes are placed more towards the centre of the area of depression (the Ponza and Lipari islands). Beyond this region we have only isolated volcanoes, such as, especially, Mount Etna and Mount Vultur, both rising out of the Macigno.

The impression produced on the author's mind by his recent journeys in Italy is that of *a low degree of stability of the mountain-chains*. At the same time the repetition of phenomena is striking, *e.g.* the concordance of structure between the Apennines and Carpathians. In the latter the northern secondary zone is almost alone visible; the ruins of the median zone are formed by the Tatra &c.; and only traces of the southern subsidiary zone appear. In the areas of depression the Hungarian trachytes make their appearance in place of the volcanoes of Latium and Naples. In both cases it is only a repetition, on a large scale, of the same phenomenon which is presented by the intra-Alpine depression of Vienna, with the thermal springs in its margins.

Some years ago Prof. Studer indicated that the western portion of the Southern Alps gradually disappears beneath the plain of Upper Italy. The investigations of Gastaldi and others fully confirm this; and thus the environs of the Gulf of Genoa show how two great mountain-ranges unite, and at the same time the central masses of both mountains sink down, with the exception of a few fragments, beneath the sea or the plain. It might even be affirmed with some probability that the sunken Tyrrhenian axis is to be regarded as the true tectonic continuation of the curved axis of the Alps themselves. The Tithonic fragments and the Cretaceous deposits of the Euganean mountains, moreover, show that between Vicenza and the Apennines the higher stages, at least, of the Mesozoic deposits are connected.

When an abstract of the views expressed in this paper was communicated to the Geological Society of Paris, Prof. Hébert remarked that in the Triassic period there existed in the north-west of the Mediterranean a continent which included Corsica, Sardinia, Elba, the Tuscan coast, and the "Maures" and Esterel Mountains in the Western Alps. This region was quite distinct from the Central Alps, and nearly of the same age as the Scandinavian mountains and the central plateau of France. This opinion may be well founded as regards Corsica, Sardinia, and the Hyères; but the eastern part of Elba is related to the Tyrrhenian central zone, exactly like a fragment of an Alpine subsidiary zone; and both in the environs of Genoa and along the Tuscan coast the strike of the crystalline formations is parallel to the direction of the Apennines. Gastaldi, who also affirms that the crystalline rocks of Western Italy form the direct continuation of the central chain of the Alps (Studii Geologici sulle Alpi occid. vol. i.), even regards the so-called serpentines occurring in the Piedmontese tertiaries and in the "Macigno" of Tuscany as the projecting peaks of the Central Alpine "pietre verdi."

[COUNT M.]

4. *On the Sulphuriferous* TERTIARIES *of* SICILY. By T. F. SEBASTIANO MOTTURA.

[Proc. Imp. Geol. Inst. Vienna, March 19, 1872, from 'Memorie per servire alla descrizione della carta geologica dell' Italia,' vol. i. p. 53, 1871.]

THESE deposits are thus divided by the author in ascending order:—

I. EOCENE. Red marls, chiefly at the base, flysch containing fucoids, often with alternating red marls, and Nummulitic limestones. In the flysch *Fucus intricatus* and *F. Targierii* abound. The Nummulitic limestones, which also frequently alternate with the flysch, contain *Nummulites Lucasanus, intermedius,* and *contortus.* Some of these beds may be Cretaceous.

II. LOWER MIOCENE.

a. Ferruginous quartzose sandstone.

b. Gypsiferous ferruginous clay.

c. Compact, cellular, or brecciiform limestones, with *Numm. perforata.*

d. Bituminous marly shales, with iron- and copper-pyrites and some small petroleum springs. North of Caltanisetta these shales contain impressions of a small fish (*Rhombus minimus*?). The Sicilian amber is probably derived from these shales. In close connexion with the limestones (*c*) a kaoliniform substance, used as soap, is found.

e. Saliferous deposits.

III. MIDDLE MIOCENE. Conglomerates, sandstones, and marls. The conglomerates, which are sometimes greatly developed, consist in part of fragments of the preceding formations. The sandstones contain *Porites incrustans, Heliastræa Ellisii, H. plana,* and *Sarcinula Michelottii.*

IV. Upper Miocene.

a. Polishing-slate composed of diatoms, with some fish-remains (*Lebia crassicauda* and *Leuciscus œningensis*). Freshwater.

b. Sulphuriferous blue marls, with gypsum; probably freshwater.

c. Marly, or sometimes tufaceous, limestone, abounding in Foraminifera identical with those of the Vienna Basin.

V. Pliocene.

a. Blue marls, with *Pinna tetragona, P. seminuda, Isocardia cor, Mytilus barbatus, M. sericeus, M. edulis, Venus multilamella, Schizaster scillæ.*

b. Tufaceous, porous limestone (much in use as a building-material) containing *Panopæa Faujasi, Pecten Jacobæus, Pectunculus insubricus, P. glycymeris, P. inflatus, Venus islandicoides, V. plicata, V. multilamella, V. pedemontana, Janira pyxidata, J. flabelliformis, Nucula placentina, N. nucleus, Lutraria elliptica, L. rugosa, L. oblonga, Pinna seminuda, P. tetragona, Natica millepunctata, Crepidula unguiformis, Cardium edule, C. sulcatum, C. fragile, Psammechinus mirabilis, Bulla lignaria, Terebratula grandis, Conus ponderosus, C. elevatus, C. Brocchii, Cladocora granulosa.*

c. Sands, sandstones, and conglomerates, the last chiefly composed of fragments of the Miocene deposits on which they rest. At the base there is usually a great oyster-bed, which forms a good geological horizon. The organic remains found here are *Ostrea edulis, O. gibbosa, Hinnites crispus, H. sinuosus, Nucula placentina, N. Polii, Venus multilamella, V. minima, Panopæa Faujasii, Cardium multicostatum, Cardita rhomboidea, C. pectinata.*

[Count M.]

5. Geology *of the* Peninsula *of* Mangischlak (*Caspian Sea*). By E. von Eichwald.

[Proc. Imp. Geol. Inst. Vienna, May 7, 1872.]

Liassic, Middle Jurassic, and Cretaceous deposits are represented in this peninsula. Certain argillaceous shales and sandstones on the Little Karatan are probably the equivalents of the lias of the Crimea. The Brown-coal deposits of the peninsula appear to be connected with beds characterized by *Ammonites Parkinsoni.* A Neocomian bed is indicated especially by *Ammonites consobrinus.* The Aptian stage is but slightly represented. The Gault contains an abundance of fossils, including *Ammonites interruptus* and *A. splendens.* The Turonian horizon is marked by *Inoceramus angulosus,* and the Senonian by *Belemnitella mucronata* and *Ananchytes ovatus.* To this group the author also refers an " Upper Chloritic Chalk," with *Nummulites supracretaceus,* which overlies the bed with *Belemnitella.*

[Count M.]

6. *On the* Geology *of* Istria. By Dr. G. Stache.

[Proc. Imp. Geol. Inst. Vienna, June 30, 1872.]

The author proposes to regard the series of strata including the "Cosina beds" as being intercalated between the uppermost Cretaceous and the oldest Tertiary (Nummulitic) deposits, and gives them the name of the "Liburnian stage." He subdivides this stage into:— 1, Upper Foraminiferal Limestones; 2, Cosina beds; and, 3, Lower Foraminiferal Limestones. Each subdivision is more or less developed, and sometimes even locally wanting; but everywhere beds characterized by the presence of *Charæ* are to be found among them. The Upper Foraminiferal limestone is marine, with intercalated estuarine deposits. The Cosina beds contain Melaniidæ and colonies of terrestrial shells; and the lowest subdivision consists in part of lenticular aggregations of coal, filling up the troughs in the surface of the cretaceous deposits; and in parts where it lies regularly stratified upon the latter, it contains intercalated beds rich in Foraminifera similar to those which also occur in the upper Rudista-beds. The upper horizons are connected with the Eocene deposits by the presence of *Alveolinæ,* and the first appearance of marine Gasteropods andBivalves of genuine Eocene type.

The Liburnian group marks the period when the bottom of the Istrio-Dalmatian Cretaceous sea, after its first emergence above the sea-level, was formed into a coast-region with many estuaries. The period during which the lower portions of the emerged dry land were again covered by the sea coincides with the highest development of the Alveoline and Orbitolite faunas, and with the first appearance of Nummulites. Some neighbouring regions, however, remained dry; and part of them have continued so uninterruptedly even to the present time. The fauna and flora of the "Liburnian group" are quite different from those of the newest Cretaceous or oldest Eocene deposits in any other known region, furnishing a strong argument in favour of its being regarded as a distinct stage.

[Count M.]

7. *The* Tertiaries *of* Messina *and* Gerace (*Calabria*). By T. Fuchs.

[Proc. Imp. Acad. Vienna, June 20, 1872.]

In this paper the author refers more especially to the system of Coralline Limestones and white marls which constitute the "Terrain Zancléen" of Seguenza, and are regarded by him as an independent group of deposits intermediate between the Miocene and Pliocene. The author considers that these beds form essentially a deep-sea deposit coeval with the "Astian" subdivision. Like the Mediterranean deposits of the Vienna Basin, the Miocenes of Messina are divided into two horizons by a bed of clay; and the distribution of fossil shells in these two horizons is the same in the neighbourhood of Messina and in the Vienna Basin. [Count M.]

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TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described, and those of which the names are printed in italics are also figured.]